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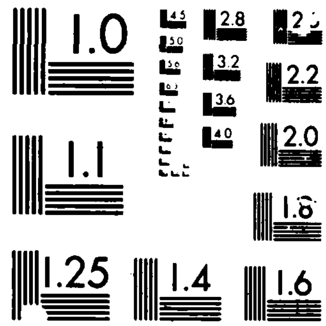
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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California



# THESIS

A PRELIMINARY DEVELOPMENT OF A

NUCLEAR PROPULSION OFFICER ENLISTMENT SUPPLY MODEL

by

Paul T. Serfass, Jr.

September 1986

Thesis Advisor: Paul R. Milch
Co-Advisor: George W. Thomas

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19. ABSTRACT

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# A Preliminary Development of a Nuclear Propulsion Officer Enlistment Supply Model

by

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Lieutenant Commander United States Navy
B.S., United States Naval Academy, June 1974

Submitted in partial fulfillment of the requirements for the degree of

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## ABSTRACT

This study constructs linear forecasting models, for each of the six Navy Recruiting Areas and the Recruiting Command, that attempt to predict future United States Navy Nuclear Propulsion Officer contracts signed in any one of four fiscal year quarters, given estimates of independent supply variables included in the models. The models are developed using stepwise multiple regression analysis with ordinary least squares and are supported by historical data from fiscal years 1981 through 1985. In developing the models, the thesis examines the relationship between the contracts signed in a given quarter and the following supply variables: number of recruiters, annual goals of number of contracts to be signed, military-to-civilian pay ratio, unemployment rate, size of target population (in the form of market share), advertising and marketing costs and seasonal effects, represented by proxy variables. The assumptions of using multiple regression analysis and linear models are examined through a graphical study of the residuals and do not seem to be refuted. Each of the models are corrected for first order autocorrelation. Validation of the forecasting models was attempted by the comparison of predicted contracts signed in a quarter against new contract data obtained for fiscal year 1986. The results of the forecasting comparisons are much worse than expected. Possible causes for the large error percentages in the comparisons are mentioned in this study but not examined in detail.

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# I. INTRODUCTION

The task of recruiting high quality personnel in sufficient numbers to maintain our national defense is a highly challenging problem facing the four branches of the Armed Forces of the United States. When the economy demonstrates improvement, it becomes increasingly difficult to attract eligible young men and women into the military. Coupled with these apparent recruiting difficulties, the manning requirements of the Armed Forces at the very least remain constant or, as in the case of the Navy, are increasing in an effort to man a 600-ship Naval Force. The military recruiter is in direct competition with the civilian business community for these high quality people. Competition is also keen among the five military services. One of the areas with the strictest and highest entrance standards demanding only the most highly educated people is the Nuclear Propulsion Officer Program of the United States Navy.

## A. BACKGROUND

Within the Nuclear Propulsion Officer Program, the Navy has experienced difficulty in achieving the national recruiting goals set by the Chief of Naval Operations. Reasons, such as strict educational entrance standards, may be numerous and beyond the scope of this study. However, it might be possible to predict the number of officer accessions into the Navy's Nuclear Propulsion Program given some estimates of future economic and demographic predictions and military management policies. Such an analysis has been conducted several times and modeled with respect to enlisted recruitment. These analyses include predictive models that attempt to either forecast enlistment supply based on various explanatory variables such as studies conducted by Fernandez [Ref. 1], Shughart [Ref. 2], Hosek [Ref. 3], and Morey [Ref. 4], or determine the effectiveness (significance) of certain marketing practices, as depicted by Carroll et al's and Goldberg's studies [Refs. 5,6] with respect to the recruiting process for the Armed Forces. Morey and McCann's paper [Ref. 7:pp. 708-715], provides a good reference for past studies conducted with respect to supply prediction models for various enlisted classification categories. The basis of these studies provided a background for this paper in developing forecasting models that predict Nuclear Propulsion Officer accessions.

The Navy Recruiting Command (NRC) divides the United States into six recruiting areas (NRA) and forty-three recruiting districts (NRD) with the districts reporting to the area commanders and the area commanders reporting to the recruiting command in Washington, D.C. Figure 1.1 displays a map of the United States with the recruiting districts and areas superimposed.

To project future accessions for the Navy Nuclear Propulsion Officer Program new contracts, multiple regression is applied to five years of historical data in fiscal year quarters from 1981 through 1985. This analysis focused on the effect certain controlled and uncontrolled variables had on the number of Nuclear Propulsion Officer program contracts (NUPOCS) written within the recruiting command.

First examined are the Navy/military management policies such as dedicated Navy Nuclear Propulsion recruiter force size, goals, military pay, and advertising and marketing costs used to recruit Nuclear Propulsion Naval officers. Second, the analysis also took into account economic indicators measured by the unemployment rate, the seasonal effect (measured by fiscal year quarters), and civilian pay. Demographic data are included in the model reflecting the location, within the United States, of the population group suitable for enlistment into the Navy Nuclear Propulsion Officer program. The cohort, or target market, is confined to college students seeking degrees in technical curriculums. These demographic data are measured by a percentage of each recruiting region's market to the total market.

## B. OBJECTIVES

The objective of this study is to attempt to explain the relationship between nuclear propulsion officer enlistment achievement (measured by contracts signed in a fixed time interval) and factors that might be expected to affect the recruiting effort. Secondly, the study develops management tools, in the form of mathematical equations, that forecast Navy Nuclear Propulsion Officer contracts for future fiscal years by quarter.

Regression analysis can be applied to forecast a single dependent variable based on the value and the relations between one or more independent variables. The intent of this study is to use multiple regression analysis and the method of least squares on historical data, representing several explanatory variables believed to influence Nuclear Propulsion Officer recruiting, to determine an equation and parameters that effectively forecast enlistments. Justification for inclusion of the predictor variables into the

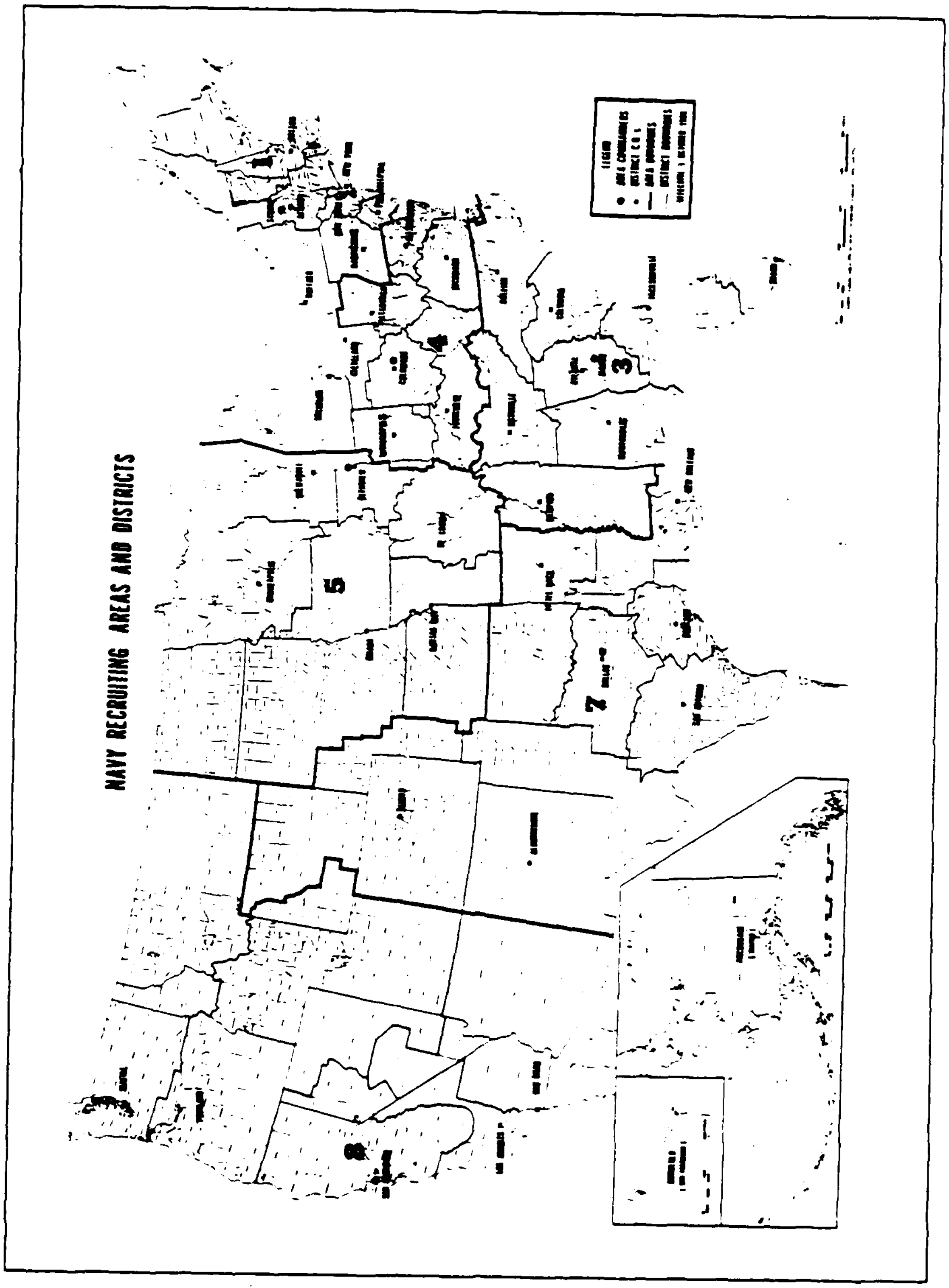


Figure 1.1 Navy Recruiting Command

models are stated. Models are developed for each recruiting area and the recruiting command using only those factors which significantly affect recruiting in that region. Major assumptions of regression analysis are examined to determine the validity of the model. The significance of the model and parameters are tested with an analysis of variance. Once the forecasting models are developed, they are validated by predicting the number of contracts written for the Navy Nuclear Propulsion Officer Program the Navy could anticipate writing for fiscal year 1986, and comparing the estimates to actual figures obtained by the recruiting command.

## C. MEASURE OF EFFECTIVENESS

The measure of effectiveness (MOE) this study uses to determine the appropriate forecasting models for predicting the number of contracts each area and recruiting command can expect to attain in a quarter is determined through examination of the $R^2$ and F statistics and the parameter estimates of the regression model. The $R^2$ statistic, also referred to as the coefficient of determination, is the percentage of variation explained in the model and should be greater than 0.80 [Ref. 8:p. 417]. This statistic measures the proportion of total variation about the mean of the dependent or response variable explained by variations in the explanatory variables. In general, the greater the $R^2$ value the better the fit of the model. The F-statistic is an indicator of the level of significance of the regression. Not only must the value of the F-statistic exceed the tabulated value calculated for degrees of freedom, but when the model is to be used for forecasting, it should be four times greater, as stated in Draper and Smith's *Applied Regression Analysis* [Ref. 8:p. 93]. Lastly, the parameter estimates are examined to ensure the model behaves as expected.

# II. DATA AND METHODOLOGY

The forecasting models developed in this study will attempt to give the Navy some indication of the number of officer contracts for the Nuclear Propulsion program the recruiting command can expect in a future fiscal year quarter for each recruiting area. This prediction would be based on estimates of government policy decisions, economic indicators, and demographic trends. This chapter demonstrates the rationale for including the variables chosen and indicates the effects each should have on the supply of Nuclear Propulsion Officers.

## A. CONTRACT FORECASTING MODEL

A variety of forecasting techniques are available, that are based exclusively on historical explanatory observations, to predict future estimates of a particular response variable. In the case of this study, it is desired to be able to predict future Nuclear Propulsion Officer new contracts (from here on referred to as contracts or NUPOCS). The claim is that there exists a basic underlying pattern that explains the relationship between contracts signed in a quarter and factors that may affect decisions to choose the Navy Nuclear Propulsion Program Officer program. These factors include military management policies, economic conditions, and population. Mathematically speaking, the relationship is postulated to be:

$$NUPOCS = f(RECTRS, RATIO, UNEMP, GOAL, MKTSHR, ADVER, TIME) \qquad \text{(eqn 2.1)}$$

with Table 1 offering a brief explanation of the names of the variables used in equation 2.1. This study chooses a technique that allows the user of the model to consider a variety of explanatory variables in an attempt to explain the number of contracts. The relationship between the explanatory and response variables is assumed to be linear. The quantitative forecasting method used to develop the linear equation is stepwise multiple regression analysis and the method of least squares.

The basic linear form of the forecasting model to be constructed is expressed as:

$$Y = X\beta + E \qquad \text{(eqn 2.2)}$$

where Y = Vector of the dependent variable NUPOCS (N x 1 matrix)

X = Matrix of independent variables (given by Table 1) (N x M matrix)

$\beta$ = Vector of parameter coefficient estimates (M x 1 matrix)

E = Vector of random errors (N x 1 matrix)

N = Number of Observations

M = Number of Independent Variables in the Model

TABLE 1

MODEL VARIABLES

| Variable | Explanation |
|---|---|
| NUPOCS | Number of Nuclear Propulsion Officer New Contracts |
| RECTRS | Number of Dedicated Nuclear Propulsion Officer Recruiters |
| RATIO | Military to Civilian Pay Ratio |
| UNEMP | Total Area Unemployment Rate |
| GOAL | CNRA NUPOCS Annual Goal |
| MKTSHR | Percent of Target Market Share |
| ADVER | Local Advertising Costs |
| QTR1 | Variable equal to one for the first quarter of the fiscal year and 0 otherwise |
| QTR2 | Variable equal to one for the second quarter of the fiscal year and 0 otherwise |
| QTR3 | Variable equal to one for the third quarter of the fiscal year and 0 otherwise |

The parameter coefficient estimates ($\beta$) are interpreted as the effect of a one-unit change in an explanatory variable on the predictor variable, all other things held constant. $\beta$ is calculated by ordinary least squares, assuming the relationship between X and Y is linear, given by equation 2.2 where $\beta$ is estimated as:

$$\beta = (X'X)^{-1} X'Y. \qquad \text{(eqn 2.3)}$$

The error term is the amount the dependent variable prediction ($Y^*_i$) differs from the observed value and is calculated by:

$$E_i = Y_i - Y^*_i \qquad \text{(eqn 2.4)}$$

Several assumptions must be made regarding the error term or what are more commonly referred to as residuals. For the model to be accurate, all of these assumptions must be checked as part of the model verification. The assumptions include that the residuals are independent and identically distributed normal random variables with zero mean and constant variance over the range of observations. The constant variance assumption, referred to as lack of heteroscedasticity [Ref. 9:p. 181], implies the variance does not change over the range of observations. The assumption of independence between the residuals, or more precisely, zero autocorrelation, states that the values of the error terms are not related to past errors. For correlated errors, corrective action is taken through a transformation of the values of the included variables. See Chapter 3.D.4. This study formulates a linear equation including only variables that prove significant in explaining the variation in contracts signed in a quarter within each designated region. First, a detailed explanation of each variable and justification for inclusion in the forecasting models is required.

## B. RESPONSE (DEPENDENT) VARIABLE

*Nuclear Propulsion Officer New Contracts* (*NUPOCS*). The response or dependent variable to be predicted relates to the numbers of Nuclear Propulsion Officers the Navy can expect to recruit. The number of contracts signed and not accessions into the Navy Nuclear Propulsion program are treated as the dependent variable. Number of contracts signed in a quarter is believed to be a better direct reflection of the factors that affect recruiting then the number of accessions would be during a given period. This is especially true considering that contracts can be signed up to two years prior to accessing into the Navy as delineated in the Nuclear Propulsion Officer Candidate Program Authorization Standards.

A factor that has had an effect on the number of enlisted personnel accessions is the easing of the entrance standards during periods of extremely difficult recruiting. In a study conducted by Goldberg [Ref. 10:p. 14], this practice is examined. However, this does not appear to be the case within the Nuclear Propulsion Program. Standards

set forth in the program authorization for the NUPOCS program have been clear and unchanged over the years examined in this study and waivers are rarely granted if at all.

The NUPOCS data are extracted from two different memorandums found within the recruiting command. The first is the memorandum regarding prospective personnel expected to be interviewed for the month by the director of the Navy Nuclear Propulsion Program. The second involves the results of the above interviews with the number of contracts signed.

## C. PREDICTOR (INDEPENDENT) VARIABLES

We assume the supply of Navy Nuclear Propulsion Program Officer contracts depends on several factors. This section explores factors that logically seem to explain possible variations in the results of the recruiting effort in the Nuclear Propulsion Officer program. These factors, or some combination of these factors, have been explored in past studies and are not new attempts at explaining the fluctuations in the number of enlistments.

The supply factors explored, as related to Nuclear Propulsion Officer new recruit contracts, are grouped into three main subcategories. These are:

- Navy/Military Management Policies: Recruiter strength, CNRC area goals, and area advertising and marketing costs;
- Relative Economic Factors: Unemployment rate, military and civilian pay, and seasonal effects; and
- Demographic Factors: Target Population.

### 1. Navy/Military Management Policies

*Recruiter Strength. Within each* recruiting district, there are recruiters assigned the specific responsibility of accessing qualified college students or graduates into the Nuclear Propulsion Officer Programs. One would expect the number of dedicated Nuclear Propulsion Officer Programs recruiters (DNR) assigned to each recruiting area to have an effect on the number of new contracts initiated each month. The recruiter conducts job fairs at local college campuses, recruiting people in the same fashion as major corporations. Results of questionnaires are screened and promising leads are followed up in an effort to recruit candidates for the Nuclear Propulsion Program. The recruiters are usually the first point of contact the prospective candidate has with the Navy and therefore are the source of initial impressions and factual information regarding the Nuclear Navy. This information includes pay and benefits, educational

opportunities, and employment possibilities. The recruiters also serve as an initial screening and processing station, examining each candidate's merits and past academic achievements in an effort to determine if the candidate meets the minimum requirements. This is accomplished through personal interviews, background investigations, and the initial screening of required documents. It can be expected that the number of recruiters would have a strong influence on the number of Nuclear Propulsion Officer new contracts signed each quarter.

Several assumptions are made with respect to the recruiter and his efforts in recruiting the desired cohorts. First is the assumption that recruiters are alike, in that each dedicated Nuclear Propulsion Officer Program recruiter is a capable and efficient naval officer, carefully selected and screened for the task. Each recruiter is expected to access his or her fair share of officers each year and work equally hard in an attempt to meet his or her district's annual goal. Additionally, DNR's are the only recruiters who recruit officers for the Nuclear Propulsion Program. Finally, the efforts of the recruiter is not accounted for in the same quarter as the new contracts signed. Therefore, the variable associated with recruiters is lagged, as shown in the model developed by Carroll et al [Ref. 5:p. 365], by the approximate time necessary for a recruiter to take a prospective candidate from initial contact to interview and contract signing. This period of time may average up to two quarters. The stepwise regression procedure allows the model to choose the best representation of recruiter strength.

The number of dedicated Nuclear Propulsion Officer recruiters assigned to each district is extracted from the District Personnel Report (NAVCRUIT 1111/1) submitted monthly to Commander Naval Recruiting Command (CNRC) by each recruiting area. Initially, only the total number of officers assigned to the recruiting district is reported. To calculate the number of recruiters tasked with Nuclear Propulsion Officer recruiting, the number of Officer Production Recruiters needed to be calculated by subtracting the officers not involved with actual recruiting. This included the district commanding officers, executive officers, enlisted programs officers, and officers in charge of 'A' stations. Once the number of Officer Production Recruiters were established, the number of dedicated Nuclear Propulsion Recruiters was extracted from the total using guidelines set forth in a CNRC Memorandum [Ref. 11] which established the Dedicated Nuclear Propulsion Recruiter Force. The policy established basic rules requiring a certain number of officers to be assigned as Dedicated Nuclear Propulsion Officer Recruiters. This number was based on the number of Officer

Production Recruiters attached to each district with the exact numbers formulated by RADM Miller's policy gram. Table 2 dictates these guidelines.

TABLE 2
RADM MILLER'S DNR COMPUTATION RULES

| *Officer Production Recruiters* | *DNR* |
|---|---|
| 3-5 | 1 |
| 6-9 | 2 |
| 10-12 | 3 |
| 13-15 | 4 |

In July 1983, the reporting format of the District Personnel Report was modified such that each district was required to report the number of Nuclear Propulsion Officer Recruiters assigned. From then on the number of DNR's is read directly from the monthly report.

With CNRC Policy-Gram No. 22-83, the national total of DNR's was set at 73, and is to remain constant even if the number of annual goals increased or decreased. These recruiters are to be proportioned in accordance to the size of the market population.

*Goals.* The Chief of Naval Operations projects the needs of the Nuclear Navy Officer Corps taking into account the projected attrition and manpower requirements of the Nuclear surface and subsurface navies. The national goals are based on these predictions and the recruiting areas are tasked, through recruiting command, with the responsibility of meeting these goals. It is assumed these goals are realistic, fair and achieveable within the spectrum of assets available to the recruiting areas. Goals are assigned in terms of contracts to be signed in a year and not accessions into the Navy. Goals are allocated based on overall percentage or share of the eligible population within the recruiting area compared to the national totals.

As previously stated, national goals have proven difficult to attain. Area recruiters can be expected to continue to recruit Nuclear Propulsion Officers aggressively regardless of whether they have exceeded their own annual goal. The reward system outlined in the Navy Recruiting Command Competition System

(NRCCS) Field Guide [Ref. 12] ensures that recruiters continue to recruit candidates for the Navy Nuclear Propulsion Officer Program actively, due to the incentives associated with exceeding goals. The purpose of the NRCCS is to support the attainment of CNRC goals by providing an objective measure of the recruiting areas and districts' recruiting performance in both officer and enlisted categories. It attempts to stimulate the production through a system of rewards for recruiting effort measured in the number of new contracts signed. Weighting factors are assigned based on current fiscal year recruiting priorities. Nuclear Propulsion Officer new contracts are in the forefront of importance. In fact the system for rewarding NUPOCS new contracts are linear over the entire range of attainment by the formula:

$$\text{POINTS} = (\text{ATTAINMENT}/\text{GOAL}) \times \text{WEIGHT} \qquad \text{(eqn 2.5)}$$

where ATTAINMENT is the total number of contracts signed in the current fiscal year, and GOAL is the number of contracts to be signed during the fiscal and WEIGHT is a value of .170. This value of WEIGHT is substantially greater than those assigned to other programs. The other programs are not nearly as generous with the rewards.

*Advertising Costs.* The advertising costs are also included in the model in an attempt to determine the significance of the costs of recruitment of officers into the Nuclear Propulsion program. Advertising costs included in this model are costs associated with local or regional advertising and marketing. This includes the cost of placing advertisements in local publications or local telecommunication stations. This dollar value is the amount spent by the recruiting area in local advertising in an effort to recruit officers for the Nuclear Propulsion program. These costs do not include national advertising.

Advertising costs should have a positive effect on the recruitment of officers into the Nuclear Propulsion program. As modeled by Epps [Ref. 13:p. 265], and Carrol et al [Ref. 6:p. 367], it is assumed the advertising costs should be lagged in the model by a period of time (up to two quarters), to better associate the subject costs with recruitment. It is expected that as advertising costs increase, recruitment increases.

### 2. Economic Factors

*Unemployment Rate.* Historical unemployment rate figures used in this study are generated by the Bureau of Labor Statistics. The variable to be used represents the

percent of the total work force unemployed in the area, not specific to the target population for the Nuclear Propulsion Officer Program. Although not specific to the white collar work force, an assumption is made that these figures are proportionally applicable to the target market. In the computation of recruiting area unemployment rate, the figures are determined by county from each state and mapped to the recruiting region. These figures are weighted by total population when utilized in the computation of the recruiting area's total unemployment rate. Forecasts of the quarterly unemployment rate are estimated by the Data Resources, Inc for the recruiting command for use in the enlisted goaling process.[1]

As the unemployment rate increases, the recruiter's job should become easier. Expected civilian earnings decrease and it becomes increasingly difficult and expensive to locate a job. Therefore an increase in the unemployment rate is expected to increase the number of Nuclear Propulsion Officer new contracts and accessions. In addition, as demonstrated in models developed by Fernandez [Ref. 1:p. 7], the independent variable representing the unemployment rate may be lagged a period of time.

*Pay.* Two pay levels, military pay and the related civilian pay, are assumed to have an effect on the recruitment of officers into the Nuclear Propulsion program. Military pay is measured by an ensign's (O-1) earnings before taxes. This figure includes base pay, basic allowance for quarters (BAQ), and basic allowance for subsistance (BAS). It does not include any incentive bonuses, compensation packages (e.g., medical or dental benefits), or variable housing allowances as included in models developed in Goldberg's study [Ref. 10:p. 19]. From figures available from the College Placement Council [Ref. 14:p. 2], civilian pay is calculated. This study surveys a fairly consistent population which includes 186 placement offices at 164 colleges and universities throughout the United States. It includes the number of job offers reported by employing organizations in business, industry, government, and non-profit organizations and the average dollar offer by curriculum. The specific technical academic majors that are used to estimate the expected civilian pay included:

- *Engineering degrees* (aeronautical, chemical, civil, electrical, industrial, mechanical, metallurgical, mining, nuclear, petroleum, and engineering technology)

[1] The Navy Recruiting Command (NRC) receives, from the CNO, a projected number of enlisted recruits the Navy needs for the following fiscal year in the form of a goal. To efficiently allocate this goal to the various recruiting areas, it considers a variety of projections, indigenous to each area, e.g., recruiter strength, unemployment rate, and population, to distribute each area's share fairly.

- *Chemistry*
- *Computer science*
- *Mathematics*
- *Physical and earth sciences.*

The data are available for the months of January, March, and July for fiscal years 1981 through 1985. Monthly civilian pay for these months when data are available is estimated as follows:

$$CIVPAY_i = \sum (N_i * SAL_i) / \sum (N_i) \qquad \text{(eqn 2.6)}$$

where $N_i$ = Number of job offers for ith technical major curriculum

$SAL_i$ = Average monthly salary offer for ith technical major curriculum.

To estimate the salary for the remaining months, the known data points are plotted against time and the estimated civilian pay interpolated from the graph. See Figure 2.1.

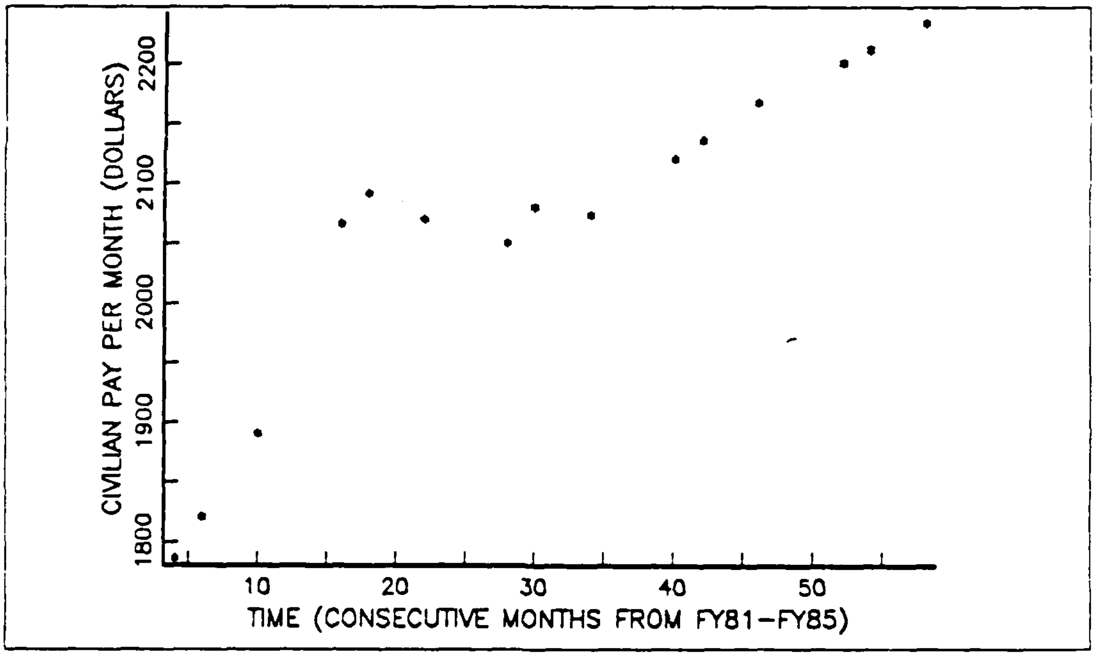


Figure 2.1 Expected Earnings
Graduating College Senior with Technical Degree

The variable representing pay can enter the model in a variety of functional forms, such as both military and civilian pay as depicted in Dertouzos's study [Ref. 15:p. 9], the difference between the two pay levels as depicted by Goldberg [Ref. 10:p. 19], or in the form of a military to civilian pay ratio as included in papers by Hosek [Ref. 3:p. 5], Fernandez [Ref. 1:p. 6], Goldberg [Ref. 6:p. 390], and Epps [Ref. 13:p. 263]. In the model developed here, pay enters into the supply model in the form of a ratio of military to civilian pay. The ratio is computed by the equation:

$$RATIO = MILPAY / CIVPAY \qquad \text{(eqn 2.7)}$$

where MILPAY = Military monthly earnings of an ensign (O1)
CIVPAY = Expected monthly earnings of a graduating college senior with a technical degree as given by equation 2.6.

An increase in the relative military pay ratio is expected to have a positive effect on the number of contracts written for the Nuclear Propulsion Officer Programs. In addition, the effect of pay may also have a lagged effect on the number of contracts signed in subsequent quarters. Therefore, RATIO is lagged up to two quarters and the regression model selects the most significant representation.

*Seasonal Effect.* Quarterly enlistment rates are believed dominated by strong seasonal patterns. The time series model for each recruiting area is chosen based on quarterly historical data from fiscal years 1981 through 1985. A graphical representation of each of the CNRA's contracts signed in a quarter versus time depicted what appears to be seasonal variation as the number of contracts signed is influenced by the time of the year. See Figures 2.2 and 2.3. The box plots of the six recruiting regions and national totals show a high number of contracts are signed during the third quarter, coinciding with the end of the majority of academic years as compared with the other quarters. On the other hand during the holiday seasons (first quarter), the number of contracts signed are small. To account for the seasonal trends, past studies by Morey [Ref. 4:p. 17], Carroll et al [Ref. 5:p. 368], and Epps [Ref. 13:p. 264], have used "proxy variables". Dummy or indicator variables are entered into the model representing each of the first three quarters. Each of these variables assumes the value one for the quarter examined and zero otherwise.

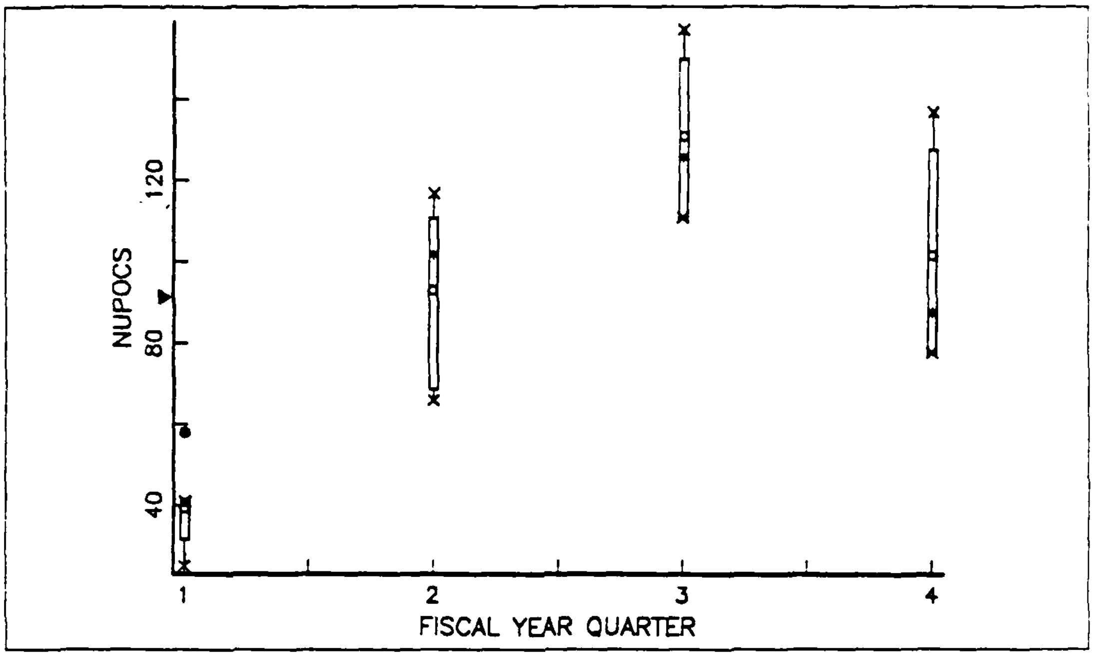


Figure 2.2 Box Plots Depicting Seasonality CNRC

3. **Demographics**

*Population* (*Market Share*). The market share represents the proportion of the national technical degrees that are granted within each recruiting area compared to the national total. Technical degrees are limited to engineering, mathematics, chemistry, computer science, and the earth and physical sciences. Within the time frame encompassed by this study, the method utilized by the Recruiting Command to determine market share varied slightly but the percentages did not change significantly in proportion with respect to the remainder of the recruiting areas. All college graduates with degrees in the study areas mentioned in the previous section are assumed eligible to be enlisted. One would expect that as the recruiting area's market share increased, the number of quarterly new contracts would also increase.

The propensity to enlist in the Navy Nuclear Propulsion Officer Program is assumed to be homogeneous throughout the nation. Attitudes regarding the naval profession are assumed to be the same within the target market i.e., white collar work force and college students seeking degrees in technical courses of study. Studies reported by the Profile of American Youth [Ref. 16], (a study sponsered by the Departments of Defense and Labor with the National Opinion Research Center and

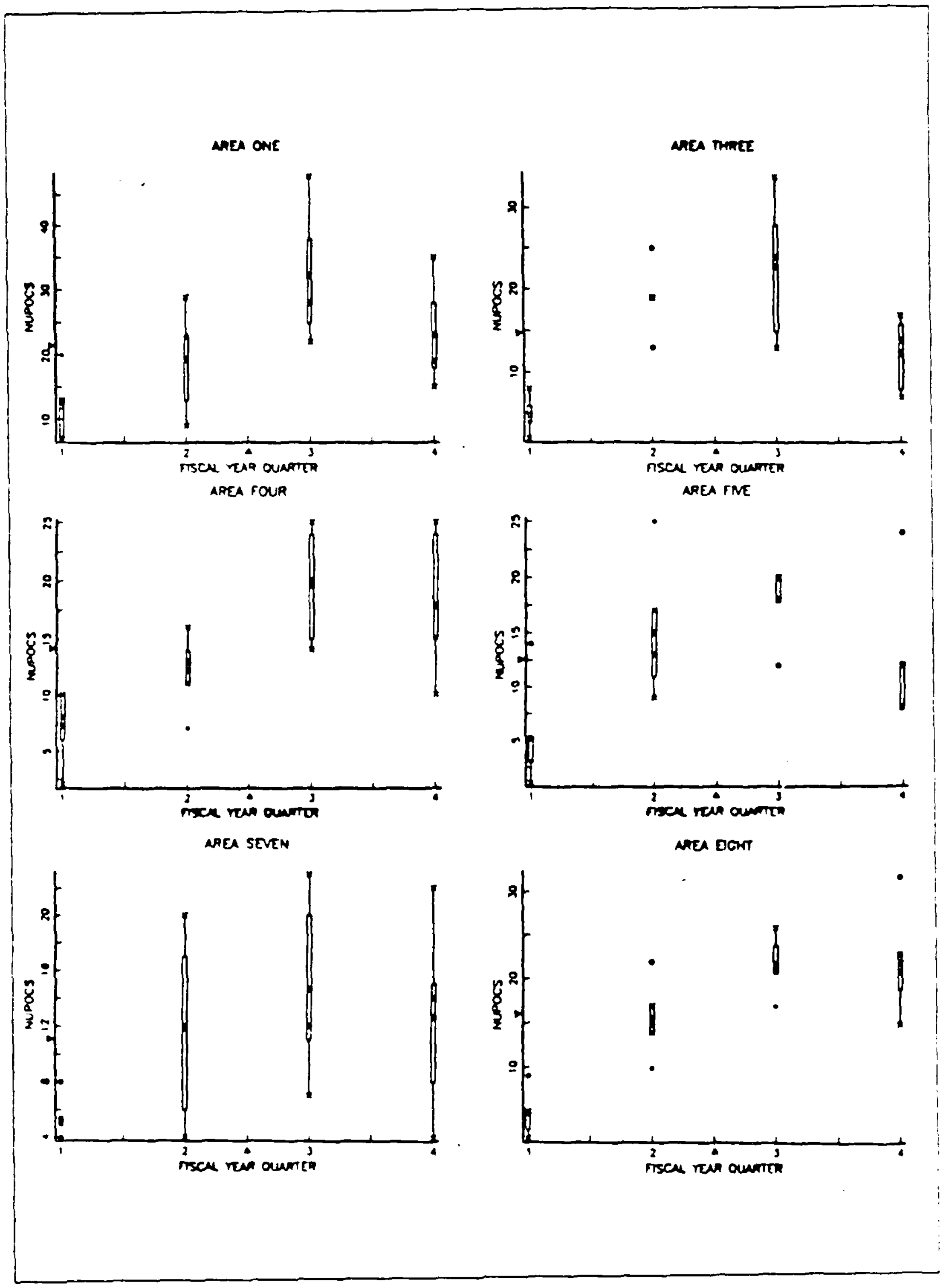


Figure 2.3 Box Plots Depicting Seasonality for NRAs 1-8

the National Longitudinal Survey of Youth Labor Force Behavior) and the Youth Attitude Tracking Study [Ref. 17] (conducted by the Department of Defense, Manpower Data Center) attempt to get some insight as to the present intentions of various target age groups to serve in the military. It is the opinion of this author that the attitudes of the population targeted by the surveys are not an adequate reflection of the attitudes of the Navy Nuclear Propulsion target market. Therefore, attitudes and propensity to enlist in the subject program is not included in the model.

# III. DEVELOPMENT AND ANALYSIS OF THE CONTRACT FORECASTING MODEL FOR NRA 8

The goal of the study, as stated, is to develop models that will forecast future Navy Nuclear Propulsion Officer new contracts signed in a quarter for the six recruiting areas and the national office (CNRC). These predictions are to be based on economic forecasts, government management policies and demographic predictions. In the previous chapter, the predictor variables relevant for inclusion in the model have been discussed. The data are obtained from a variety of sources and are thought to be reasonably accurate.

This chapter deals with the development of the predictive models. Here, the step by step procedure regarding the formulation of the forecasting model for Recruiting Area Eight (NRA 8) only is described in detail. The model is developed by stepwise multiple regression analysis and ordinary least squares (OLS), with the lagged and unlagged combinations of the appropriate variables. The assumptions of OLS multiple regression outlined in the preceding chapter are examined to determine the correctness of the model. Specifically, assumptions of normality and the lack of multicollinearity, autocorrelation and heteroscedasticity are examined and, if necessary, corrective action is taken. The remaining forecasting models for the other NRA's are developed using similar procedures and the results coupled with brief analyses, are included in the following chapter.

## A. CORRELATION AMONG EXPLANATORY VARIABLES

The relevant explanatory variables chosen in the forecasting model, especially the economic variables, are often related in general ways. For example, as the unemployment rate increases and the unemployed work force increases, it is expected that jobs are increasingly more difficult to locate. Therefore, employers may not increase starting salaries to new college graduates and in some cases may decrease starting salary offers. Thus, the unemployment rate may be related to pay. This factor is refered to as correlation. If two or more of the supply variables are correlated, the problem is referred to as multicollinearity.

If the variation in one explanatory variable is persistently related to variation in one or more of the other explanatory variables, the variation in the dependent variable

cannot be attributed accurately to a specific origin. Several negative consequences can be experienced when multicollinearity exists. One is that the parameter coefficients may not be estimated correctly. Another is that the parameter estimates may respond badly to the addition or deletion of a few observations, or the deletion of a seemingly insignificant variable. Thirdly, coefficients may not appear significantly different from zero causing the variable to be insignificant and excluded from the model and follow on analysis.

TABLE 3

CORRELATION COEFFICIENTS FOR NRA 8

| VARS | RECTRS | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|
| RECTRS | 1.00000 | | | | | |
| RATIO | -0.40449 | 1.00000 | | | | |
| UNEMP | 0.05240 | -0.42834 | 1.00000 | | | |
| GOALS | 0.56150 | -0.51175 | 0.22349 | 1.00000 | | |
| MKTSHR | -0.51711 | 0.16534 | 0.28033 | -0.69657 | 1.00000 | |
| ADVER | 0.04751 | -0.06441 | -0.12453 | 0.18198 | -0.61908 | 1.00000 |

Several methods exist that help in detecting the presence of multicollinearity, only two are explored in this study. The first method of detecting multicollinearity is through the examination of the simple correlation matrix. See Table 3. The correlation matrix can be generated using most statistical packages. As a general rule,[2] action needs to be taken to reduce the effects if the estimates of the correlation between the independent variables exceed 0.70.

An informal method utilized in the detection of correlation between independent variables is through the examination of scatter plots. The DRAFTSMAN function [Ref. 19] available in GRAFSTAT[3] is a useful tool for this purpose. The function

[2]Wheelwright & Makridakis's *Forecasting Methods for Management* [Ref. 18:p. 161], states not to use two independent variables whose simple correlation is greater than 0.70.

[3]GRAFSTAT is an experimental graphical and statistical APL package developed by IBM Research Center, Yorktown Heights, NY and available at the Naval

allows the user to examine the scatter plots of one explanatory variable plotted against another. Patterns or other hidden underlying relationships are much easier to see in the examination of scatter plots rather than tabled data. Correlated variables should show a linear relationship or trend. Figures 3.1a and 3.1b represent the plots of the variables for NRA 8 data. Variables with annual constant values are "jittered" [Ref. 20] to prevent the overlap of plotted points. The data associated with population, NUPOC annual goals and number of recruiters are jittered. For the presence of correlation, the plots are examined for positive or negative trends, indications that the explanatory variables are related.

Several techniques are available to remove the effects of multicollinearity. The easiest and most practical is through the removal of one or more independent variables causing the difficulty. Another is to use weighted least squares vice ordinary least squares. If correlation is present between variables of the models in this study, one of the correlated variables is removed from the model.

The scatter plots of NRA 8 data shown in Figures 3.1a and 3.1b generated by DRAFTSMAN, allow a visual interpretation of the explanatory variables. The scatter plot of the number of recruiters plotted against NUPOC annual goals possibly shows some positive correlation. As the number of recruiters increase, it appears the goals increase. But the correlation coefficient from Table 3 between the two variables is 0.56, which is less than the value of 0.70 recommended by Wheelwright and Makridakis as the point at which one of the two affected independent variables should be discarded. The remainder of the scatter plots fail to depict any relationship between the six independent variables. The plot points in each of the other graphs appear random with no discernable trend. An examination of the remainder of the values in the simple correlation matrix of NRA 8 data reveals no correlation above 0.70. So in the case of the data explored for NRA 8, no further action is deemed necessary.

## B. CONTRACT FORECASTING MODEL SPECIFICATION

The study is now concerned with the model specification including (1) that relevant variables have been included in the model; (2) that irrelevant variables have

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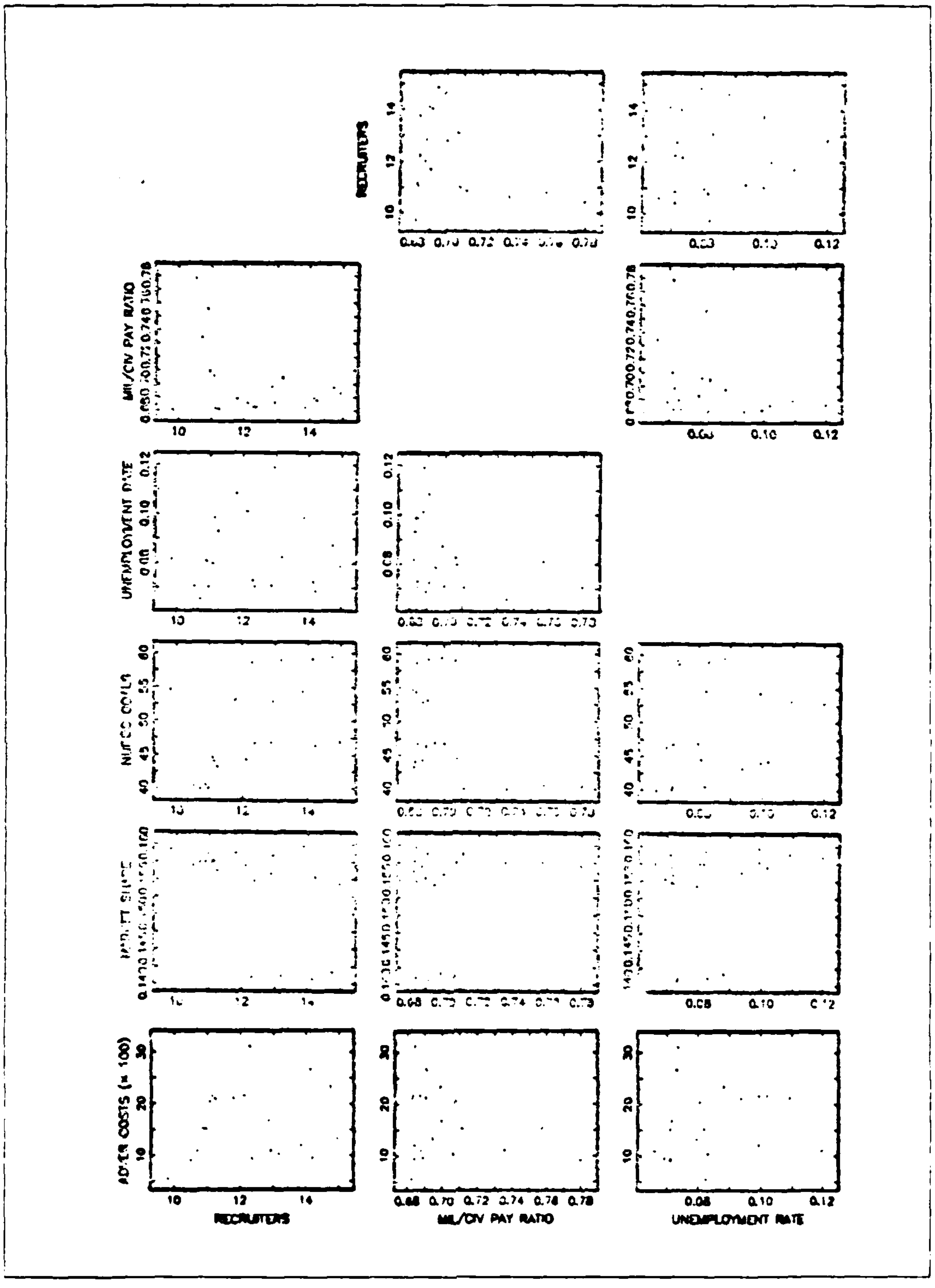


Figure 3.1a DRAFTSMAN Scatter Plots for Correlation

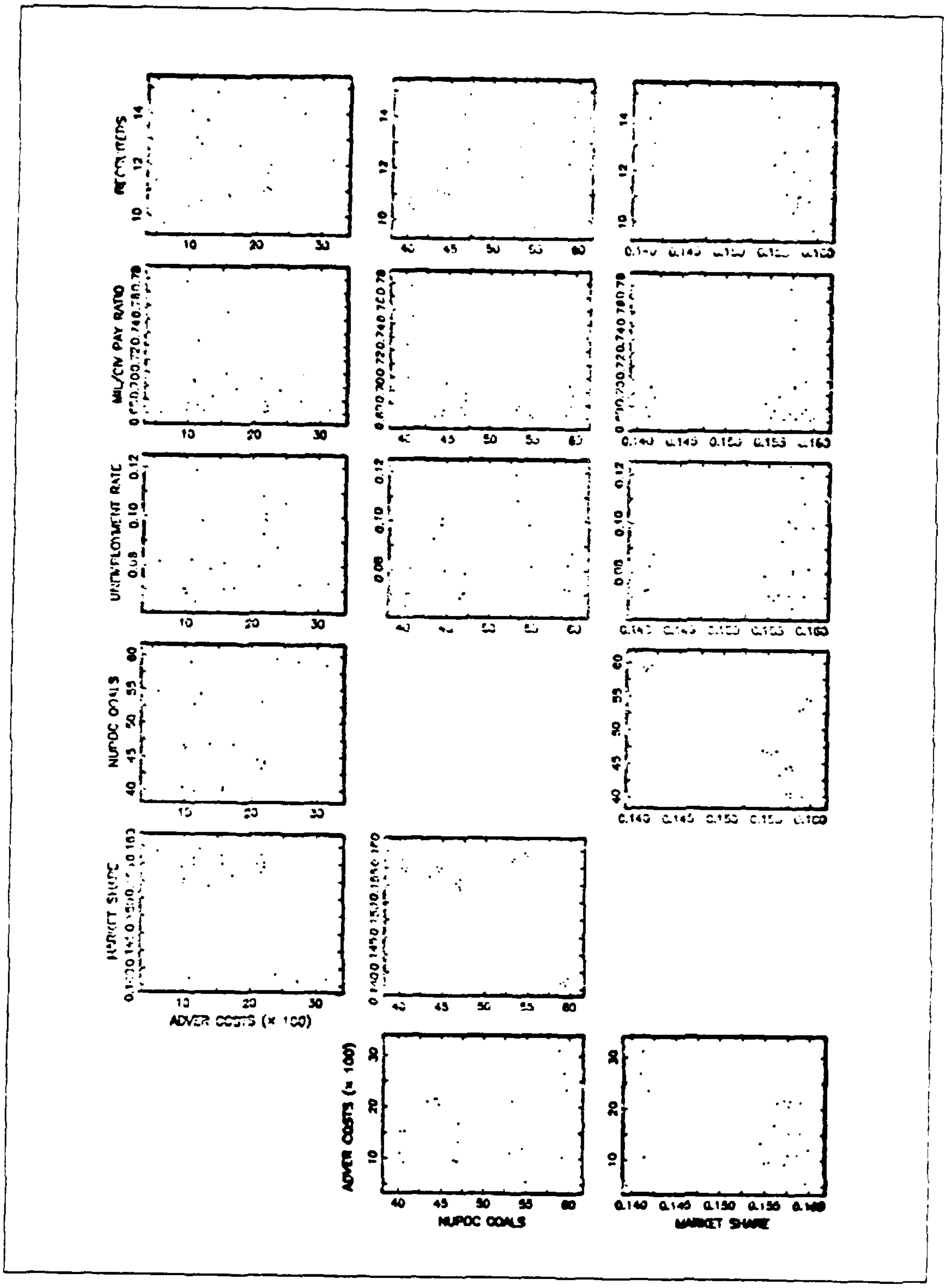


Figure 3.1b DRAFTSMAN Scatter Plots for Correlation

not been included in the model, and (3) whether the correct functional form has been used to estimate the relationship between the dependent variable, NUPOCS, and the various explanatory variables.

Omitting a relevant variable or including an irrelevant one from the regression equation will both cause unreliable coefficients of the model and "biased" estimates. In Chapter 2, it was explained why each variable should be included in the model. If, on the other hand, an irrelevant variable has been inadvertently added for analysis, the standard errors of the parameter estimates of the relevant variables will increase. In addition, the significance of the estimates will not be as great, as shown by the t-statistic. Adding unnecessary variables will cause the relevant variables to be less significant than actual.

A basic assumption made in this study is that there is a linear relationship between the variables in the forecasting model. Choosing the incorrect functional form of the model could cause the coefficients of the model to be biased. To detect the presence of a nonlinear relationship, the study examines the residuals of the models plotted against the independent variables. If a nonlinear relationship exists, a sinusoidal curve should be present. After each forecasting model is developed, this assumption is tested by examining the forementioned plots for the presence of a nonlinear relationship.

## C. CONTRACT MODEL FORMULATION AND VARIABLE SELECTION

Models can be constructed which include lagged variables of either the independent or the dependent variables or both. Lag models are referred to as such because the influence of the explanatory variables on the dependent variable is distributed over past values of the independent variables.

As discussed in Chapter 2, variables associated with advertising and marketing costs (ADVER), the number of recruiters (RECTRS), the military-to-civilian pay ratio (RATIO), and the unemployment rate (UNEMP) may have a lagged effect on the number of contracts signed in subsequent quarters. To account for this possibility, OLS regression is performed with all lagged and unlagged variables to determine which of the explanatory variables seem to have some effect on the number of Nuclear Propulsion Officer Contracts signed in a quarter. Stepwise regression provides us with a means of determining the "best" regression equation by examining all the different combinations of the lagged and unlagged independent variables. It does so by

selectively adding and removing explanatory variables from the model based on the significance the variable adds to the model. Initially, each of the nine independent variables, plus lagged representations of recruiter strength, unemployment rate, military-civilian pay ratio, and advertising costs, are included in the stepwise procedure. Variables are examined for entrance into the model based on the partial correlation coefficient with the dependent variable. The variables enter the equation and the overall regression is checked for significance, the $R^2$ value is noted and the F-values for all the variables in the equation are examined. The lowest F value of the explanatory variable in the model is compared against the level ($\alpha$) of significance of 15 percent. The procedure repeats itself until all candidate variables are examined and variables, if significant, are entered, one at a time, into the model. If no variable meets the significance criteria, the model adopted is the uninteresting case where the best prediction of the dependent variable is just its mean.

The stepwise procedure selected unemployment rate (not lagged), as well as seasonality factors representing fiscal year quarter one and two, as significant and to be included in the forecasting model for NRA 8. A multiple regression model results using the selected variables UNEMP, QTR1, and QTR2. The required statistics and residuals are generated and utilized in verifying the assumptions and significance of the model.

## D. ANALYSIS OF RESIDUALS

To determine if our fitted model is correct, a graphical study of the residuals should confirm the assumptions of the multiple regression model, or at the minimum, not refute them.

### 1. Assumption of Model Specification (Linearity)

The residuals of the forecasting model developed by multiple regression analysis are plotted against the unemployment rate data for NRA 8 to dispute the assumption that the relationship between explanatory and response variables is something other than linear. A plot of the residuals in Figure 3.2 shows no discernable pattern to be present in the NRA 8 Contract forecasting model. Therefore, the relationship is assumed to be linear.

### 2. Assumption of Normality

The residuals of the regression model are fitted to a normal distribution and plotted in a histogram in an attempt to refute the normal assumption. By Figure 3.3, the residuals appear to have a mean of zero. The cumulative distribution function plot

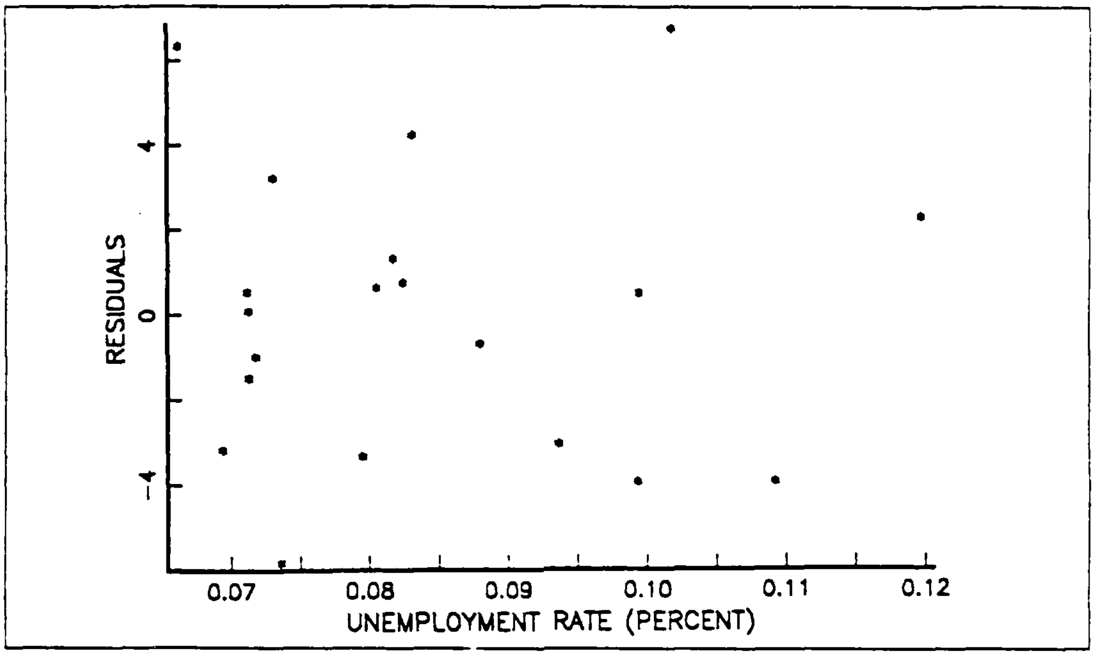


Figure 3.2 Residuals vs Explanatory Variable

in Figure 3.4 shows the residuals fit a normal distribution fairly well. Goodness of fit tests by Kolmogorov-Smirnov fail to reject the residuals are not distributed normally. Figure 3.5 of the plot of the residuals against the fitted values of Nuclear Propulsion Officer new contracts and Figure 3.2 of the residuals plotted against the explanatory variables also fail to show any trends in the variance. Thus the conclusion, based on the residuals from the regression on NRA 8's data, is that the errors are normally distributed with zero mean.

3. **Assumption of Constant Variance (Lack of Heteroscedasticity)**

Also associated with the study of the residuals is the assumption of constant variance to go along with the normality assumption. The errors are assumed not to be dependent on any explanatory variable. When this assumption is violated, heteroscedasticity is said to be present. If present, plots of the residuals might show a distinct pattern over the range of the explanatory variable, like a change in magnitude or sign direction (i.e., positive to negative). Heteroscedasticity effects the size of the standard error of the parameter coefficient, thus transferring the error along to the results and the residuals.

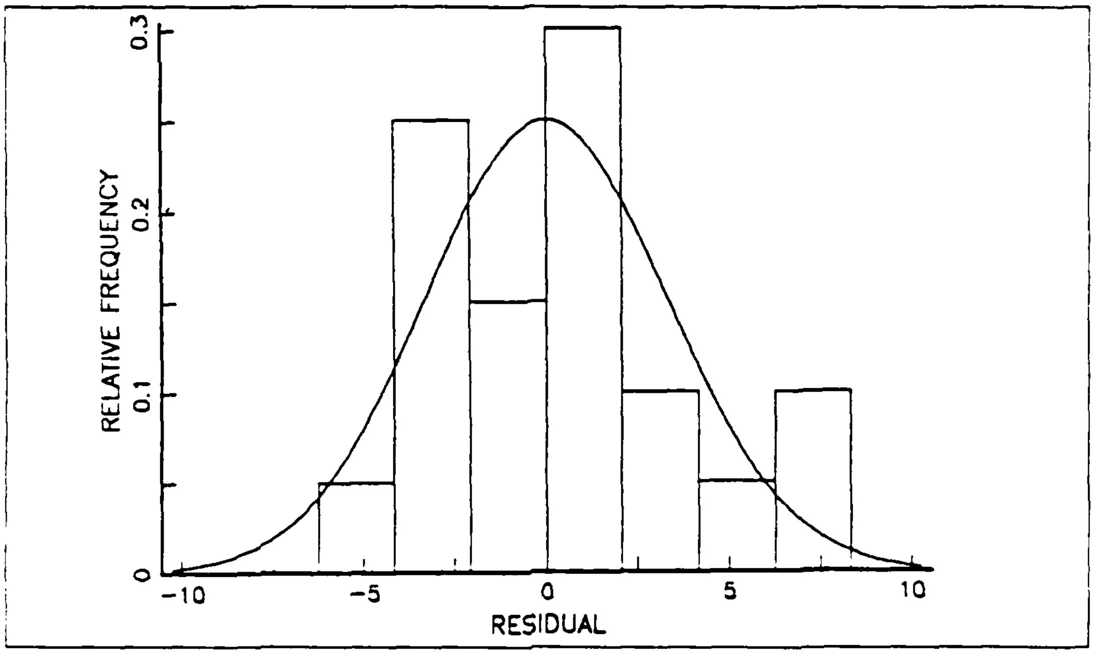


Figure 3.3 Histogram of Residuals

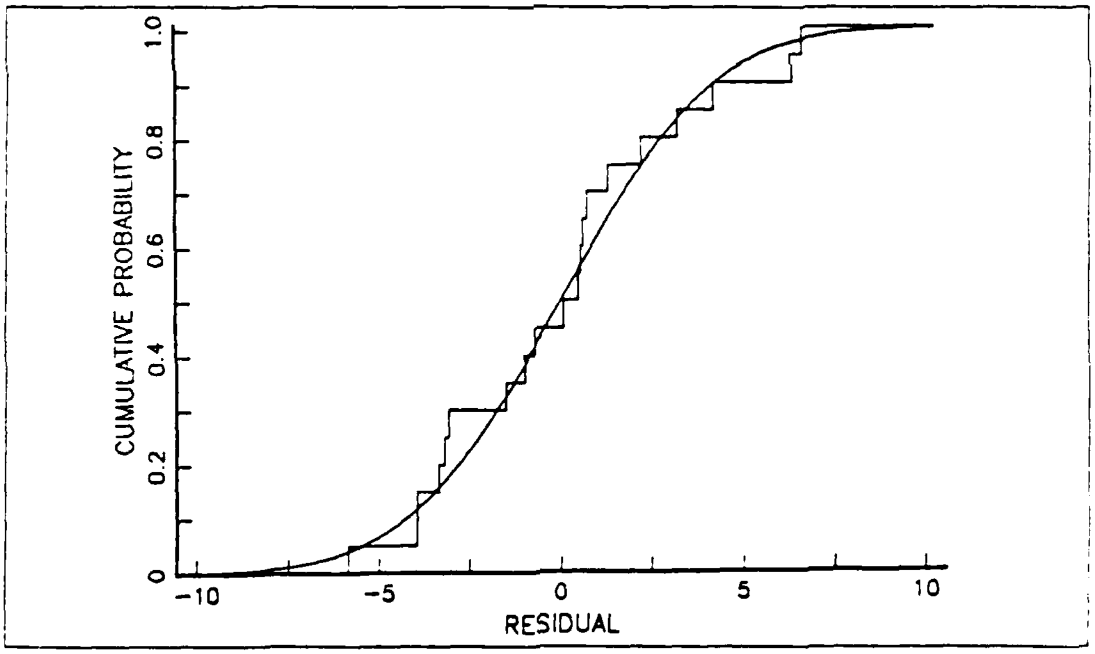


Figure 3.4 Cumulative Distribution Function (CDF) Plot

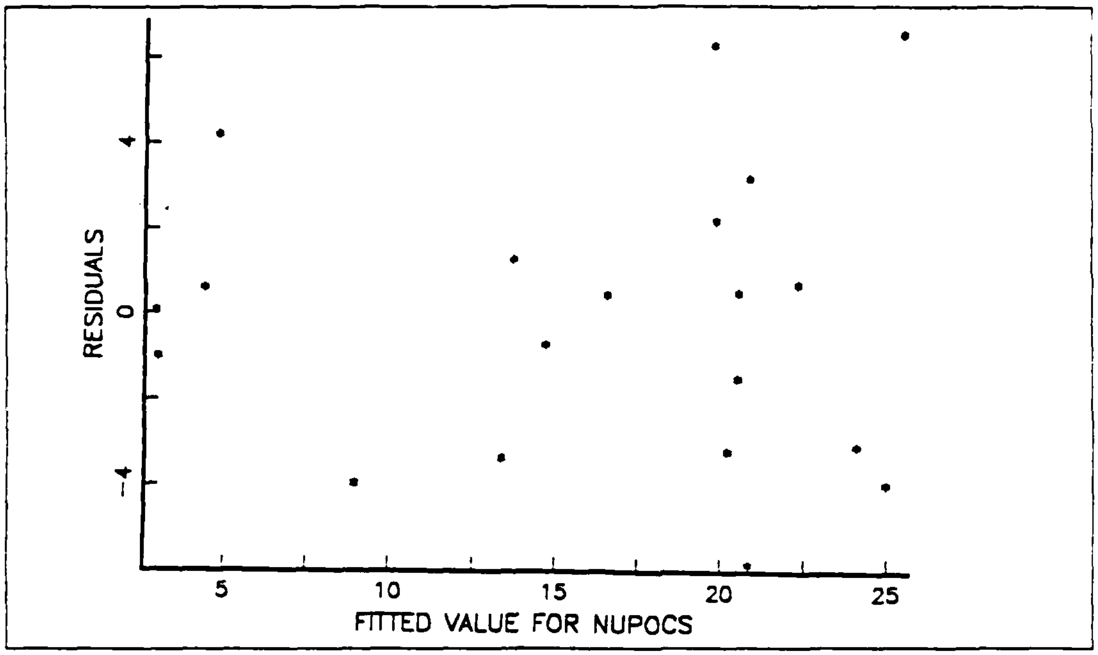


Figure 3.5 Plot of Residuals vs Fitted Values of Contracts

To test for the presence of heteroscedasticity, scatter plots of the residuals of the regression model against each one of the explanatory variables are constructed. As shown in Figure 3.2 for NRA 8, the residuals do not appear to be correlated with the independent variable representing area unemployment rate. A time sequence plot (Figure 3.6) reveals no apparent long term time trend with an increasing or decreasing variance. Therefore no further action is deemed appropriate.

4. **Assumption of Independence (Lack of Autocorrelation).**

Initially the study assumes that the residuals are independent and uncorrelated over time. This implies:

$$\mathrm{Var}(E) = \boldsymbol{\sigma}^2 \, I \qquad \text{(eqn 3.1)}$$

where I is the N × N identity matrix. Autocorrelation or serial correlation refers to the situation where the errors of the regression of any time period are correlated with errors of the previous times. This implies:

$$\mathrm{Var}(E) = \boldsymbol{\sigma}^2 \, \boldsymbol{\Psi} \qquad \text{(eqn 3.2)}$$

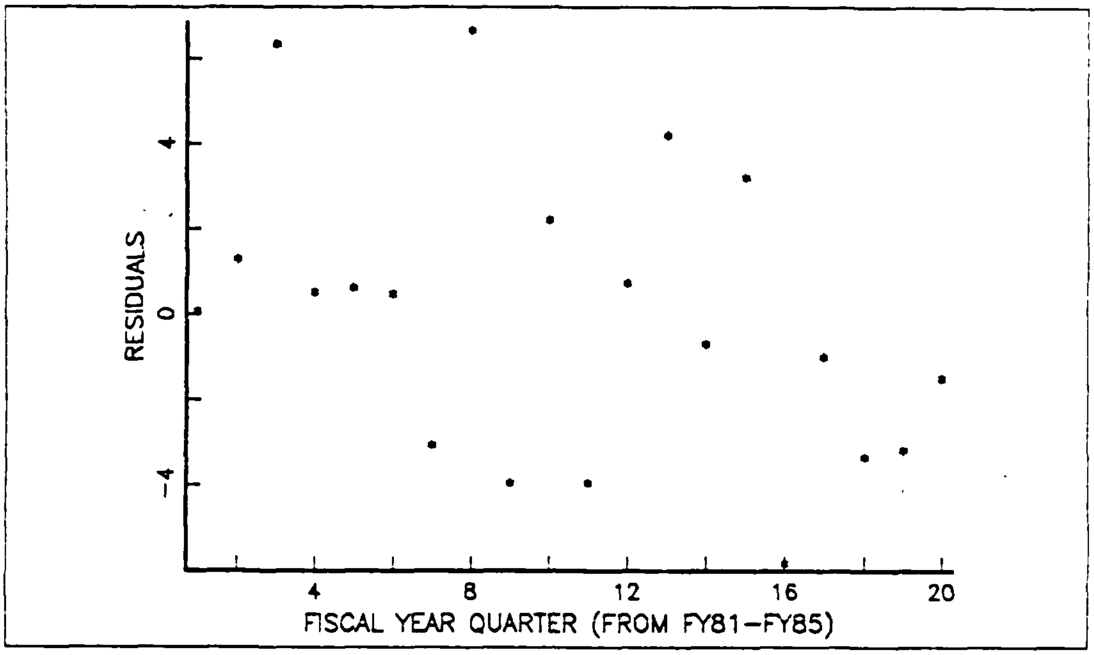


Figure 3.6 Time Sequence Plot

where $\Psi$ specifies the structure of the covariance matrix of the residuals and is a real positive definite symmetric matrix [Ref. 21:p. 289] given below by equation 3.5. It can be caused by omitting one or more independent variables, by the wrong model specification, or by the effects of the explanatory variables' dependence on time. This condition violates one of the stated assumptions of the OLS regression that the errors are independent. In this study if present, autocorrelation is examined in the simple linear relationship between two successive error terms $E_{t-1}$ and $E_t$ (refered to as first order autoregressive scheme) by the equation:

$$E_t = \rho E_{t-1} + V_t \qquad \text{(eqn 3.3)}$$

where $V_t$ is another random error term assumed to have zero mean, constant variance and uncorrelated over time and $\rho$ is the correlation coefficient between the consecutive error terms $E_{t-1}$ and $E_t$. Most economic variables associated with time series models tend to display autocorrelation. Autocorrelation, going undetected, causes the parameter estimates to appear more reliable than they actually are in reality. This serial correlation can be detected informally via graphical means or more formally through the Durbin-Watson statistic.

A rough idea of the presense of autocorrelation and its pattern can be realized by plotting the regression residuals versus the residuals lagged by one quarter. In Figure 3.7, there appears a pattern of residuals that might indicate negative correlation is present. A more traditional test for the presence of autocorrelation in the model is the Durbin-Watson test which is applicable to small sample sizes ( < 30) as well as large ones. The null hypothesis that the errors are not autocorrelated:

$$H0: \ \rho = 0$$

is tested against the alternative hypothesis that the errors are autocorrelated:

$$H1: \ \rho \neq 0.$$

The Durbin-Watson statistic (DW) is calculated as part of most regression packages. If the value of the statistic lies between 0 and 2, some degree of positive autocorrelation is present. The closer the value of DW is to 0, the greater the autocorrelation. If between 2 and 4, negative autocorrelation is present in the model. The closer to 4, the greater the negative autocorrelation. With a Durbin-Watson value of 2.469 calculated, in this case, some degree of negative autocorrelation is present, but the formal Durbin-Watson test is inconclusive in this case.

If first order autocorrelation is present in the errors or if formal and informal testing for the presence of it is inconclusive, the appropriate corrective procedure is to take into account the serial correlation. Referring to equation 3.3 the value for $\rho$ must be estimated and the values for the observations transformed thus removing the effect of serial correlation.

As previously stated one must first estimate the correlation coefficient. One of the mathematically more convenient methods of estimating the true value of the correlation coefficient, and the one used in this study, is to use the relationship:

$$\rho^* = 1 - DW/2 \qquad \text{(eqn 3.4)}$$

In most econometric books (e.g., Refs 9,21:pp. 222,443), one can find a more detailed explanation of serial correlation and derivation of $\rho^*$ as a reliable estimate for $\rho$ .

Once an estimate of the correlation coefficient is calculated, the appropriate transformation matrix (P) is constructed [Ref. 21:p. 441]. The matrix (P) transforms the values of the historical data to account for the presence of first order serial correlation and is defined by:

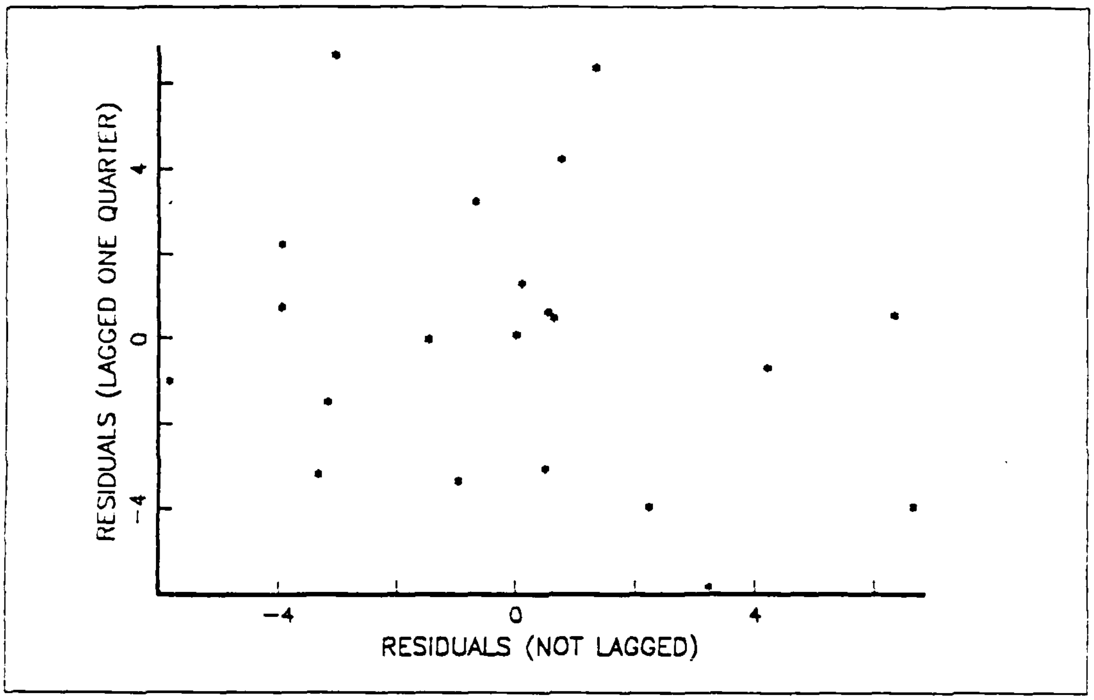


Figure 3.7 Lag-1 Serial Plot of Residuals

$$P = \begin{bmatrix} \sqrt{1-\rho^2} & 0 & 0 & 0 & . & . & . & 0 \\ -\rho & 1 & 0 & 0 & . & . & . & 0 \\ 0 & -\rho & 1 & 0 & . & . & . & 0 \\ 0 & 0 & -\rho & 1 & . & . & . & 0 \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & . & . & -\rho & 1 \end{bmatrix}$$

and

$$P^{-1} P = \Psi^{-1} . \qquad \text{(eqn 3.5)}$$

The values for the variables used in the initial regression model are transformed, by $Y^* = PY$ and $X^* = PX$, and new values for the independent and dependent variables are calculated. The basic form of the linear model becomes:

$$Y^* = X^* \beta + E^* \qquad \text{(eqn 3.6)}$$

The transformed observations are regressed using OLS and new estimates for the parameter coefficients ($\beta^*$) are obtained. The equation of the forecasting model in its final form is depicted as:

$$Y = X \beta^* + E \qquad \text{(eqn 3.7)}$$

The APL program listed in Appendix C calculates the estimate for $\rho$ using the Durbin-Watson statistic and transforms the observations to be used in the regression equations.

## E. PARAMETER ESTIMATES AND ANALYSIS OF VARIANCE

Results of the regression, based on the variables the stepwise procedure selected for NRA 8 and corrected for autocorrelation, are depicted in Table 4 The results of the regressions for the remaining recruiting areas are contained in Appendix D.

The equation of the form of equation 3.7 that results from the regression that is to be used to forecast contracts signed in a quarter for NRA 8 is:

$$NUPOCS_t = 8.89 + 162.21\ UNEMP_t - 17.48\ QTR1 - 8.54\ QTR2 \qquad \text{(eqn 3.8)}$$

Each of the estimates of the parameter coefficients, given in Table 4, are examined to determine if the values are significantly different from zero. Each estimate ($\beta^*$) is examined by formal means testing the null hypothesis that $\beta^*$ is equal to zero against the alternative that $\beta^*$ is not equal to zero. The t-statistic is compared with the Student's t-distribution value at a 95% confidence level with 19 degrees of freedom. The value of the test statistic with 19 degrees of freedom is 1.725 which is less in absolute value than each t-statistic in Table 4 Therefore, in each case, the null hypothesis is rejected and the alternative accepted.

TABLE 4

PARAMETER ESTIMATES & ANOVA - NRA 8

| VARIABLE | $\beta^*$ | STD ERROR | t-statistic |
|---|---|---|---|
| INTERCEP | 8.89 | 4.11 | -2.166 |
| $UNEMP_t$ | 162.21 | 49.45 | 3.280 |
| QTR1 | -17.48 | 2.00 | -8.760 |
| QTR2 | -8.54 | 2.12 | -4.032 |

| SOURCE | DF | SS | MS | F VALUE |
|---|---|---|---|---|
| MODEL | 4 | 8906.2 | 2226.6 | 171.68 |
| ERROR | 16 | 207.5 | 12.969 | |
| C TOTAL | 20 | 9113.7 | | |

| | | |
|---|---|---|
| R-SQUARE | 0.98 | STD ERROR = 3.60 |
| ADJ R-SQ | 0.97 | |
| Durbin-Watson | 2.47 | |

From the ANOVA table (displayed in Table 4), the study examines the F value (171.68) to determine the significance of the regression. This value is the mean square due to regression divided by the mean square due to residual variation, both divided by their own degrees of freedom. The resulting ratio follows an F distribution and is compared with a tabled F statistic value of 3.59, with two and seventeen degrees of freedom at the 95% confidence level. The observed mean-square ratio of 171.68 exceeds this F-value. This is an indication that a statistically significant regression has been obtained for NRA 8, and that the proportion of the variation observed in the data, which has been accounted for by the forecasting equation, is greater than a 95% chance for similar sets of data. Also from the ANOVA table, the percentage of variation about the mean of the response variable explained ($R^2$ ) may be examined. The $R^2$ value is .98.

After correcting for autocorrelation and to insure the fitted model is correct, residuals are examined to insure the assumptions have not been violated. The residuals are graphically analyzed and found not in violation of the basic assumptions with respect to the errors being independent, identically, and normally distributed random variables with mean of zero and constant variance. Figures 3.8 and 3.9 are representative samples of graphs reaffirming the normality and constant variance assumptions.

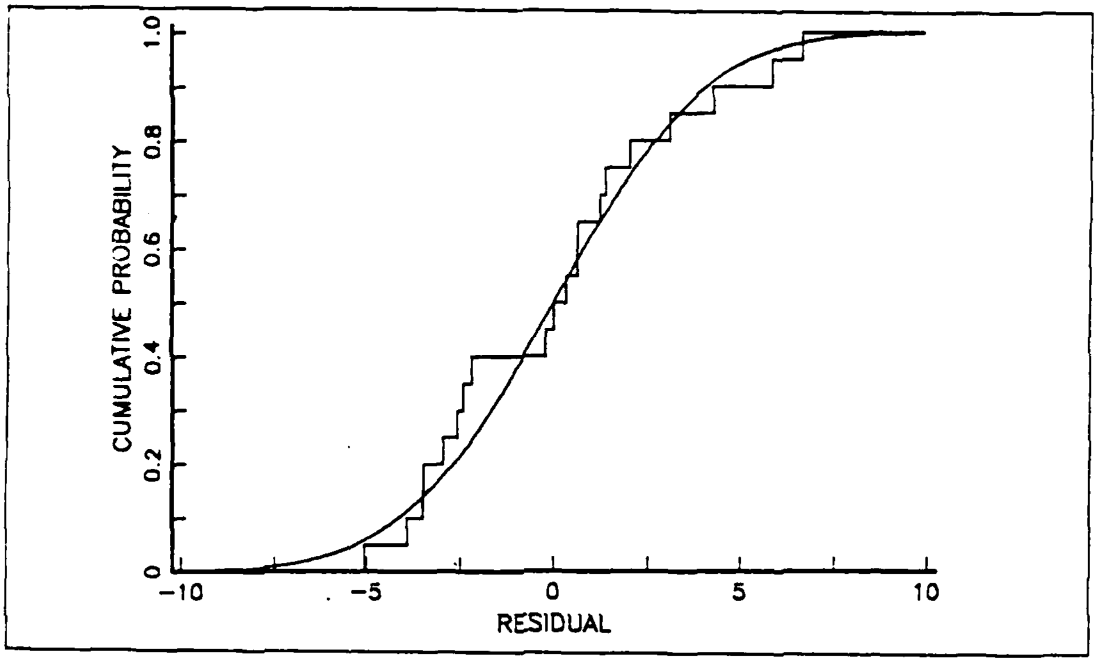


Figure 3.8 Cumulative Distribution Function Plot

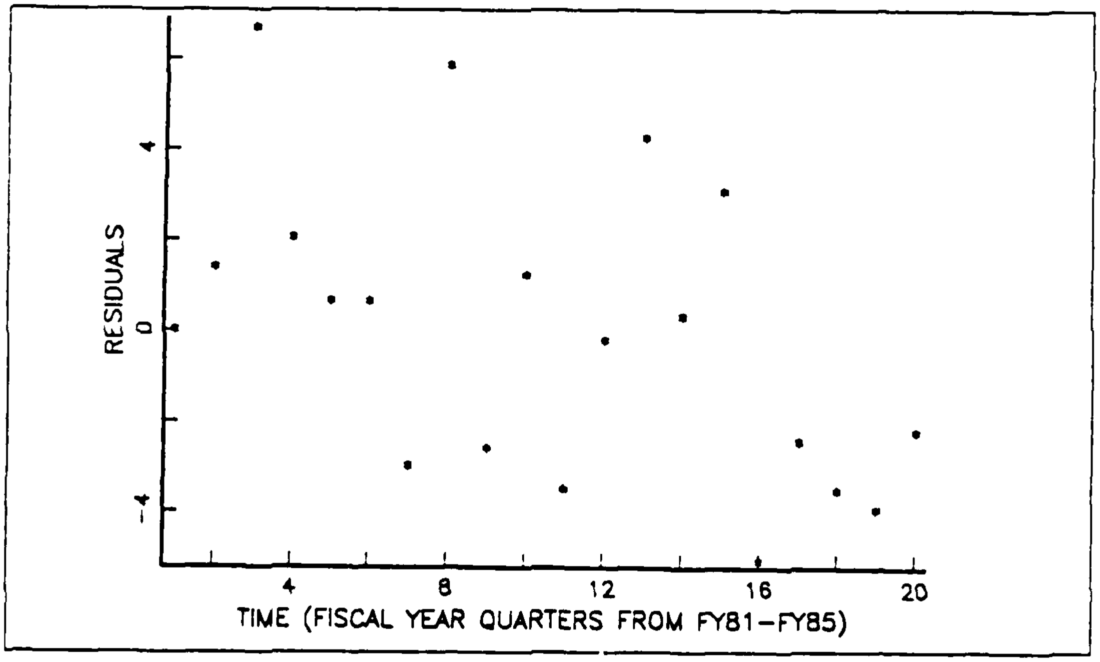


Figure 3.9 Time Sequence Plot

## F. ANALYSIS OF NRA 8 FORECASTING MODEL

The independent variables selected by the stepwise procedure that do the best of explaining the fluctuations in the number of contracts signed in a quarter are the unemployment rate (not lagged) and two seasonality proxy variables representing fiscal year quarters one and two. No other variables, including variables lagged one or two quarters, showed to be significant in explaining the changes in contracts. The variables selected in seasonality could have been anticipated. Examining the box plots depicting the number of contracts signed in each quarter (see Figure 2.3) there appears to be no significant difference between contracts signed in the third and fourth quarter. But, there appears to be a difference between contracts signed in the first and second quarters and the third/fourth quarters. The model takes this into account.

The explanatory variable associated with the recruiting area's unemployment rate, with no lagged effect, is also shown to affect contracts signed. From the coefficient estimates of the parameters, given in Table 4, as the unemployment rate decreases, so will the expected number of contracts signed in the same quarter.

This model (as well as the remaining forecasting models developed in this study) does not imply that the remaining variables do not effect the number of Navy Nuclear Propulsion Officer contracts signed in a quarter. Recruiters, advertising, pay and goals all play an important role in the recruiting process. Significant reduction of any asset would probably cause a decrease in the numbers of contracts signed. Within the context of this model, once the variables UNEMP, QTR1, and QTR2 are included in the forecasting equation, the remaining variables (e.g., ADVER, RATIO, etc) do not significantly impact on the number of contracts beyond the effect of the three variables included.

# IV. CONTRACT FORECASTING MODELS FOR OTHER NRA'S

Forecasting models, that predict Navy Nuclear Propulsion Officer contracts for the remaining five recruiting areas and the recruiting command, are constructed in a similar fashion to the one developed in the previous chapter for Navy Recruiting Area Eight (NRA 8). The relationship between the dependent and independent variables is assumed to be linear. The stepwise regression procedure selects the predictor variables found most significantly affecting contracts signed in a quarter. Multiple regression analysis produces the linear forecasting equations. The residuals of the resulting models are examined to test the validity of the multiple regression assumptions. Each model is corrected for autocorrelation, using the Durbin-Watson statistic and the transformation in equation 3.4 as an estimate for $\rho$, to obtain estimates for the parameter coefficients ($\beta^*$).

This chapter analyzes each of the six remaining models of the form of equation 3.7 with only the significant explanatory variables included. The predictions of future contracts for each quarter of fiscal year 1986 are calculated and compared to the actual numbers of contracts signed in the year in the following chapter. Tables containing the estimates and analysis of variance for each model can be found in Appendix D.

## A. NAVY RECRUITING AREA 1 (NRA 1)

$$NUPOCS_t = -62.21 + 663.28\,(UNEMP_{t-1}) + 2.15\,(RECTRS_{t-1}) - 10.54\,(QTR1) + 3.98\,(QTR3) \qquad \text{(eqn 4.1)}$$

The stepwise regression procedure indicates that both the previous quarter's unemployment (UNEMP lagged one quarter) and recruiter force size (RECTRS lagged one quarter) significantly influence the number of contracts signed in a quarter. In addition, seasonality proxy variables representing the first and third fiscal year quarters also significantly contribute to the forecasting model. The tables in Appendix B indicate that the variables UNEMP and RECTRS are not significantly correlated (-0.208). All parameter coefficient estimates are significant at $\alpha = 0.10$ (i.e., $\beta \neq 0$). Multiple regression assumptions of the model are examined, tested and found to be valid. In some cases, some negative autocorrelation is present (Durbin-Watson

statistic = 2.305) and therefore, the variables are transformed ($\rho$ = -0.1525, and regression analysis is applied to the resulting variables. Equation 4.1 represents the forecasting model for Navy Recruiting Area One. The $R^2$ value is considered to be more than adequate (0.98) and an examination of the F-statistic (122.47) indicates the linear model is significant.

## B. NAVY RECRUITING AREA 3 (NRA 3)

$$NUPOCS_t = -40.04 + 388.72\,(MKTSHR_t) - 7.31\,(QTR1) + 6.94\,(QTR2) + 10.92\,(QTR3) \qquad \text{(eqn 4.2)}$$

Of the seventeen combinations of lagged and unlagged variables included in the initial analysis, the seasonality dummy variables for all three quarters and the share of the market influenced the numbers of Navy Nuclear Propulsion Officer contracts signed in a quarter. An examination of the resulting statistics and residuals show that the model and parameter coefficient estimates are significant at $\alpha$ = 0.05. All assumptions appear to be valid through an analysis of the residuals. Although not conclusive, the Durbin-Watson test (DW = 2.90) does not reject that autocorrelation is not present. Regression analysis is applied to the transformed variables ($\rho$ = -0.45) and equation 4.2 is developed as the forecasting model for the recruiting area. An interpretation of this model is that from year to year, the number of contracts will increase (or decrease) as the percentage of the population eligible to be recruited into the program increases (or decreases). The historical data showed that NRA 3 has produced a consistent share of contracts, irrespective of the changing economy or government policies.

## C. NAVY RECRUITING AREA 4 (NRA 4)

$$NUPOCS_t = 0.14 + 179.62\,(UNEMP_{t-1}) - 10.23\,(QTR1) - 5.72\,(QTR2) \qquad \text{(eqn 4.3)}$$

Again the unemployment rate, lagged one quarter, is shown to significantly affect the number of contracts signed. The $R^2$ value is satisfactory (0.96) and the model developed by the regression analysis is significant (F-statistic = 98.15) at $\alpha$ = 0.01

level. The parameter estimates for unemployment rate and the first and third quarters are significant at the 0.95 percent level. The usual assumptions about the residuals are verified. The negative autocorrelation is accounted for by transforming the variables ($\rho^* = -0.110$), reapplying the data to regression analysis, and the forecasting equation (equation 4.3) is formulated.

## D. NAVY RECRUITING AREA 5 (NRA 5)

$$NUPOCS_t = 2.52 + 151.08\,(UNEMP_{t-1}) - 7.82\,(QTR1) \qquad \text{(eqn 4.4)}$$

The explanatory variable found to influence the variation in contracts signed in a quarter is unemployment rate. Variation of contracts signed in any given quarter is only significantly different in the first quarter. The assumption of multiple regression analysis with a linear model specification is confirmed to be accurate. Coefficients of the parameter estimates are significantly different from zero at least at the 95 percent level. The forecasting model for NRA 5 indicates that the number of contracts expected in the last three quarters are roughly the same, affected only by the unemployment rate of the previous quarter. Expected numbers of contracts for the first quarter are 7.82 contracts less than the average of the last three quarters and are also affected by the unemployment rate.

## E. NAVY RECRUITING AREA 7 (NRA 7)

$$NUPOCS_t = -8.06 + 226.08\,(UNEMP_{t-1}) + 0.0006\,(ADVER_{t-1}) - 7.85\,(QTR1) \qquad \text{(eqn 4.5)}$$

The linear forecasting model for NRA 7 shows that the variables associated with unemployment rate (lagged) and advertising costs (lagged) explain the variation in contracts signed. The proxy variable for quarter one explains the variation between the first quarter and the remaining three quarters. The model assumptions are carefully examined and found to be correct. The historical data is corrected for autocorrelation ($\rho^* = -0.020$) and multiple regression analysis applied to the transformed variables. All coefficients of the estimates of the parameters are significant.

Again the unemployment rate from the previous quarter affects contracts signed in the analyzed quarter. Advertising costs, from the previous quarter, also seem to have a positive significant affect on the numbers of recruits. This could be an indication that the money is well spent by the recruiting command, i.e., increased advertising causes an increase in numbers of contracts.

## F. NAVY RECRUITING COMMAND (NRC)

$$NUPOCS_t = -30.43 + 1189.1\,(UNEMP_{t-1}) + 0.12\,(GOALS_t) - 64.08\,(QTR1) - 23.49\,(QTR2) + 27.83\,(QTR3) \qquad \text{(eqn 4.6)}$$

For the Navy Recruiting Command forecasting model, the historical data of the various recruiting areas are aggregated, or national statistics obtained if appropriate (e.g., unemployment rate) and the stepwise procedure applied. The explanatory variables selected as explaining the variation in contracts signed are unemployment rate (lagged one quarter), goals, and the fiscal year quarters. After applying multiple regression analysis to the selected variables, the resultant statistics showed the model to be significant. An analysis of the residuals showed the assumptions to be valid. Negative autocorrelation is present, the data is transformed, and regression analysis is applied to the transformed data ($\rho = -0.179$).

# V. CONTRACT FORECASTING MODEL VALIDATION

Forecasting models, for each of the recruiting areas and the recruiting command, have been developed using historical data from fiscal years 1981 through 1985. In this chapter, the study forecasts contracts (NUPOCS) for each quarter of fiscal year 1986, based on economic and government military predictions of the explanatory variables. To assess how well the developed models forecast, the predicted number of NUPOCS were compared with the actual numbers attained by the recruiting command in FY86. This procedure was recommended by Draper and Smith [Ref. 8:p. 420] as a method of model validation, and used by Morey [Ref. 4:p. 25] in his analysis of forecasting enlisted recruits.

The forecasting model equations were of the form:

$$Y_{t+1} = X_{t+1}\,\beta^{*} + E_{t+1} \qquad \text{(eqn 5.1)}$$

where $Y_{t+1}$ was the forecasted number of contracts signed at time $t+1$, $X_{t+1}$ was a vector of the values of the estimated forecasted supply factors, and $\beta^{*}$ was a vector of the generalized least square estimates of the parameter coefficients of the significant explanatory variables corrected for first order autocorrelation. To account for the information that first order autocorrelation was present in the residuals of the forecasts (e.g., the errors of the predictions of the first quarter of fiscal year 1986 were correlated with the last quarter of FY85), the study applies the following equation to obtain the prediction of NUPOCS:

$$Y_{t+1} = X_{t+1}\,\beta^{*} + \rho\,(Y_t - X_t\,\beta^{*}) + V_{t+1} \qquad \text{(eqn 5.2)}$$

## A. FORECASTED EXPLANATORY VARIABLES

The predictions of the number of contracts attained in a given quarter were based on forecasts of the economy, government policies, and demographics. The predictions for the explanatory variables' values were obtained from a variety of sources. The number of dedicated nuclear propulsion officer recruiters were the projected number of

recruiters expected onboard during the upcoming fiscal year (assumed to be the same number as the last quarter in FY85). Military pay was calculated based on an expected 3% pay raise for the Armed Services' members as of 1 October 1985. Civilian pay was estimated from Figure 2.1 regarding expected earnings of a college graduate with a technical degree through fiscal year 1985 and projected through FY86. This equated to approximately a 1% increase of pay per quarter or a 4% annual increase. Unemployment rates were forecasted for CNRC by Data Resources Incorporated (DRI) (for use in the enlisted goaling model for the following fiscal year). Market share forecasts, calculated by CNRC for use in their officer goaling model,[4] consider the percentage of the present number of college juniors and seniors in each NRA compared to the national total for the current fiscal year and uses the figure as a projection for the following fiscal year. The advertising costs, associated with Nuclear Propulsion Officer recruiting, were the monies budgeted for by CNRC and given to the NRA's to be utilized as they deem appropriate. Since the recruiting budgets were based on the previous year's expenditures, an estimate of these costs were assumed to be the same as the previous year's advertising costs.

## B. NUPOCS PREDICTIONS FOR FY 1986

Using the developed forecasting equations and the assumption that first order autocorrelation was present and accounted for by equation 5.2, predictions of Navy Nuclear Propulsion Officer contracts that could be expected in FY86 can be calculated and compared to actual contracts attained. Confidence intervals at the 95% level can also be calculated by the equation:

$$Y_1 \pm t\,((n\text{-}p\text{-}1), 0.95)\,\sigma \sqrt{(X'_1\,(X'X)^{-1}\,X_1\,)} \qquad \text{(eqn 5.3)}$$

where X was a matrix of the historical data of the significant explanatory variables, $X_1$ was a vector of the forecasted values of the explanatory variables, $\sigma$ was the estimated standard error of the model and $Y_1$ was the forecasted value for NUPOCS. Further, t (n-p-1,0.95) was the 95% point of a Student's t distribution with (n-p-1) degrees of freedom, where n was the number of observations of the historical data from 1981-1985

[4]Same as the enlisted goaling model but used for goaling the various officer programs.

and p was the number of explanatory variables included in the forecasting model [Ref. 8:p. 210].

The predicted values of the contracts signed in FY86 calculated using the developed models, were compared against the actual figures obtained by the recruiting command in Table 5. Also included in the table were the 95% confidence intervals around the predicted values of the contracts. Comparisons between the predicted and actual numbers of NUPOCS for FY86 were for the first three quarters only due to the unavailability of data for the entire fourth quarter at the time this study was completed. The actual number of NUPOCS attained was available from CNRC through the end of July 1986.

## C. ANALYSIS OF FORECASTS OF CONTRACTS

Prior to analyzing the comparison between the predicted and actual numbers of contracts signed in a quarter for fiscal year 1986, several points need emphasis. Officer program goals for Nuclear Propulsion have been exceeded for fiscal year 1986 with a full two months of recruiting remaining, an occurance that was rare and was not expected. Also, the forecasts of contracts the various models predict for FY86 were based on the estimated FY86 values of the explanatory variables, rather than the actual values. In addition, one might have expected some difficulties with unanticipated annual "one time" events that may interfere, either positively or negatively, with the recruiting process. For instance, a one year and one time bonus for enlisting in the Nuclear Propulsion Officer Program may be authorized by Congress during a period of difficult recruiting. Even if the events affecting recruiting like this one could be anticipated, it would be difficult to include them in a model.

An analysis and comparison of the forecasting models' results for FY86 contained in Table 5, show that in only two of the seven forecasting models did the number of actual contracts obtained in the third quarter of FY86 fall within a 95% confidence region of the predictions. Only the model for NRA 7 predicts contracts in an acceptable manner (less than 4% error). Actual contracts signed also fall within the 95% confidence region in all three of the first three quarters of FY86 using the forecasting model of NRA 8. Models for NRA 4 and NRA 5 and the Navy Recruiting Command (NRA 0) predict contracts within a 95% confidence interval of the actual contracts for the first two quarters but miss in the third quarter. NRA 4's model fails on forecasts for the second and third quarters, and the forecasting model for NRA 1 misses on all three quarters.

TABLE 5

FORECASTING RESULTS AND COMPARISONS FOR FY 86

| NRA | QTR | NUPOCS(P) | NUPOCS(A) | RESIDS | PERCENT ERROR |
|---|---|---|---|---|---|
| 1 | 1 | 0.8 ( 0.0, 6.6) | 8. | 7.2 | 90% |
| 1 | 2 | 13.6 ( 9.8, 17.4) | 4. | -9.6 | 240% |
| 1 | 3 | 20.1 (14.2, 26.0) | 42. | 21.9 | 52% |
| 1 | 4 | 11.4 ( 7.6, 15.1) | 7* | | |
| 3 | 1 | 0.3 ( 0.0, 5.0) | 2. | 1.7 | 85% |
| 3 | 2 | 14.6 ( 9.9, 19.2) | 14. | -0.6 | 4% |
| 3 | 3 | 19.6 (14.9, 24.2) | 13. | -6.6 | 51% |
| 3 | 4 | 10.9 ( 6.3, 15.5) | 7* | | |
| 4 | 1 | 4.4 ( 0.0, 8.9) | 6. | 1.6 | 27% |
| 4 | 2 | 10.4 ( 6.5, 14.3) | 20. | 9.6 | 48% |
| 4 | 3 | 13.7 (10.1, 17.2) | 24. | 10.3 | 43% |
| 4 | 4 | 13.1 ( 9.3, 17.0) | 10* | | |
| 5 | 1 | 6.7 ( 1.3, 12.1) | 6. | -0.7 | 12% |
| 5 | 2 | 13.7 (10.8, 16.7) | 12. | -1.7 | 14% |
| 5 | 3 | 14.4 (11.3, 17.5) | 30. | 15.6 | 52% |
| 5 | 4 | 8.1 ( 4.7, 11.5) | 5* | | |
| 7 | 1 | 3.1 ( 0.0, 9.2) | 3. | -0.1 | 3% |
| 7 | 2 | 11.4 ( 6.8, 15.9) | 11. | -0.4 | 4% |
| 7 | 3 | 14.0 (10.7, 17.2) | 14. | 0.0 | 0% |
| 7 | 4 | 13.4 (10.0, 16.8) | 4* | | |
| 8 | 1 | 3.7 ( 0.1, 7.3) | 6. | 2.3 | 38% |
| 8 | 2 | 11.6 ( 7.3, 15.9) | 10. | -1.6 | 16% |
| 8 | 3 | 20.7 (18.0, 23.5) | 22. | 1.3 | 6% |
| 8 | 4 | 19.7 (16.9, 22.5) | 10* | | |
| 0 | 1 | 27.9 (13.0, 43.0) | 31. | 3.1 | 10% |
| 0 | 2 | 64.8 (46.6, 83.0) | 70. | 5.2 | 7% |
| 0 | 3 | 114.3 (99.0,130.0) | 145. | 30.7 | 21% |
| 0 | 4 | 81.3 (66.0, 97.0) | 43* | | |

* Note: Fourth quarter FY86 data through July 1986.

Several possibilities exist for the large errors depicted in Table 5. Ascertainment of the "true" causes for such large errors were beyond the scope of this thesis but several possible causes were mentioned but not examined in detail. First was that key predicter variables could have possibly been omitted from the models during development that explained some variation in the number of contracts signed in a quarter. Another was the fact that the forecasting was based on predictions rather than the actual values of the explanatory variables. Those predictions of the explanatory variables were, of course, subject to error. For example, the unemployment rates were projected for the four quarters in FY86. These estimates, formulated by Data Resources Incorporated, were based on educated deductions from years of experience, research, and knowledge of trends in the economy. If unanticipated events occur that drive the economy stronger or weaker than predicted, the forecasts of contracts might have been off by a substantial margin. However, in this specific case, it appears that the estimates of the unemployment rate were fairly accurate forecasts of the actual rates. The large errors in the predictions of NUPOCS in NRA 1 could have also been caused by the error in predicting the number of recruiters in NRA 1. The forecasting equation depends on accurate forecasts of recruiter strength. However, once again, the predicted and actual number of recruiters did not significantly differ.

Other possible reasons exist which could explain why the majority of the models appear to predict so poorly. The model predictions for NRA 1 err by as much as 240% for the second quarter and 52% for the third quarter in fiscal year 1986. One possible explanation stems from the historical data collection and that errors may be made in its compilation and measurement. For example, the change in the method counting the number of dedicated Nuclear Propulsion Officer recruiters between June and July 1983, as stated in Chapter 2.C.1, may have contributed to the lack of agreement between the contract predictions and actual values. Excluding national expenditures from the calculation of advertising and marketing costs in the various models' development may have also accounted for the error in NUPOC predictions. The small amount of historical data available to be included in the model construction could also have contributed to the shortcomings of the final forecasting equations. If the sample size of the historical data was large enough, the outliers, indicating incorrect data, may be discovered or be absorbed by the remaining data. With small sample sizes this was much more difficult.

In general, another possible cause for the large errors with the forecasts of the number of contracts signed could have been in the model specification and development. Possibly, the assumption of linearity that described the relationship between the response and explanatory variables may not have been correct. The assumptions of linear regression analysis, e.g., lack of multicollinearity, variable selection or omission, etc., might not have been correct. However, in the case of this thesis, the assumptions of a linear regression model were examined and not refuted.

During the course of this research, an inherent assumption of the linear regression analysis was that the demand function remained stable throughout the range of each supply factor examined. This circumstance generally cannot be guaranteed. If this was not the case and the demand curve was shifting, then predictions based on the historical data would not accurately reflect the characteristics of the market supply and the proper supply function would not have been identified [Ref. 22:pp. 250-254].

Some explanation for the discrepancy between actual and forecasted values may lie within the recruiting command itself. First was the possibility of a greater recruiter effort in productivity, translated to longer productive working hours, caused by greater command involvement when earlier NUPOC recruiting results were lacking. If the Commanding Officers of the various recruiting areas received strong additional guidance from superiors to improve NUPOC production, that pressure was transmitted to the recruiters and possibly more assets were directed into a troubled area. Another factor that might have translated to increased productivity was a change in the command atmosphere, e.g., a change in Commanding Officers, that coupled with an improved working environment, equated to greater job satisfaction and improved worker productivity.

Policy changes in the recruiting command in general could also have a positive (or negative) effect on the number of NUPOCS signed in a quarter. Some of these were explored and found to be unsubstantiated. Recruiting goals were not revised, thus changing the pressure on the recruiters. Nor was the competition system (NRCCS) altered to increase the dividends of accessing Nuclear Propulsion Officers, making it more or less advantageous to recruit in the subject field. Entrance standards were not altered to enhance enlistment, but they remained as stringent as ever. Finally, monetary rewards (i.e., bonuses) for joining the Navy Nuclear Propulsion Officer Program were not increased.

Other possible explanations for the disparity between the forecasted and actual NUPOCS lie outside the Recruiting Command. Items that may cause the discrepancy between the predicted and actual numbers of contracts could be related to current events and their effects on the recruiting. These events, either political or nonpolitical, were extremely difficult to include in the model, or forecast their collective effect on recruiting in the Nuclear Propulsion Officer field. A sudden change in attitudes towards a possible career in the Armed Forces caused by current events was believed by this author to influence recruiting. Quite possibly, the events with respect to Libya[5] could have increased the patriotic spirit and national pride, thus altering the thinking of prospective enlistes to enter the Nuclear Propulsion Officer program in the third quarter, rather than choose another line of work. Within the colleges, be it in the administrators or the students themselves, different attitudes might have gained emphasis that were favorable to the military. It also seems to be human nature to follow trends and follow the lead of others. Once a few people join, trends seem to be contagious.

These were just a few examples of why the model may fail in forecasting new officer contracts for the Nuclear Propulsion Officer Program. Based on historical data, the model development used sound, viable reasoning and the results give indications the assumptions of multiple regression analysis using ordinary least squares were satisfied. This study cannot offer a definitive explanation based on fact for the less than acceptable predictions. Therefore, only some possible reasons were listed as speculation.

## D. RECOMMENDATIONS FOR FUTURE STUDIES

Several areas for continued research result from this study. Anyone of the above mentioned suspected problems could be further analyzed in a subsequent study. However, only a few possible topics are briefly mentioned as possible areas for further research.

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[5] In retaliation for repeated terrorist activities believed sponsored by the government of Libya, the United States operated Naval Forces in the Gulf of Sidra in late winter early spring of 1986. In response to a terrorist bombing in Berlin aimed at US servicemen and women, air units of the US Air Force and Navy attacked suspected terrorist targets inside Libya on 15 April 1986. The military response of the United States received overwhelming support from its citizens.

First involves the use of an alternate specification of the model, for example the use of a log-linear model vice a linear model. It is also possible the ordinary least squares regression analysis is inappropriate in this case and a nonlinear estimation technique, such as probit or logit analysis, is better. Another extension of this thesis is to explore the possibility of demand for technical curriculum college graduates shifting during the period of analysis. If the demand function is shifting, then the supply function may be identified and estimated using two step least squares (2SLS) procedures as described by Maurice and Smithson [Ref. 22:pp. 250-254]. Also, as additional data becomes available from future fiscal years, a supply variable(s) inadvertently omitted from the research is discovered, or a variation of an included variable, such as the pay variable in this study, is found to be a better representation, follow on studies might recompute the forecasting models. These are only a few possible topics for future research.

# VI. SUMMARY

The primary goal of this study was to develop management tools that aid in forecasting the number of Nuclear Propulsion Officer Program new contracts (NUPOCS) the Navy could expect to attain in future years. These tools were in the form of prediction models, one for each of the six recruiting areas (NRAs) and one for the entire recruiting command (NRC). Such models can be useful management tools in enabling the recruiting command to obtain a preliminary assessment of the number of NUPOCS the various regions can attain in the future. The forecasting models developed in this research attempted to predict, within a 95% confidence region, the expected number of NUPOCS the recruiting areas might attain. The models were based on the assumption that there exists a linear relationship between the number of contracts signed in a fiscal year quarter and the explanatory variables representing recruiter strength, unemployment rate, military vs civilian pay, NUPOC annual area goals, target population, advertising costs, and seasonal effects.

The models were developed using multiple regression analysis and ordinary least squares (OLS) on historical data from fiscal years 1981 through 1985. Significant explanatory variables were selected based on the stepwise regression procedure, and forecasting equations were formulated. Assumptions surrounding the use of linear models and multiple regression were tested through the examination of the residuals to insure verification of correctness of the prediction models. All models were corrected for first order autocorrelation. Using an application of the Durbin-Watson test to obtain an estimate for the amount of serial correlation, the historical data was transformed and OLS applied to obtain corrected estimates of the parameter coefficients.

Even though the unemployment rate used was the percentage of the total work force not employed, vice the unemployment rate within the target market, this variable proved significant in six of the seven forecasting models in the prediction of NUPOCS. NRA 3's model excluded the unemployment rate but includes the target population (market share) as an explanatory variable. Recruiter strength in NRA 1, advertising costs in NRA 7, and NUPOC annual goals for the NRC model were also significant in predicting NUPOCS within their respective regions.

Predictions of the number of Nuclear Propulsion Officer Program new contracts expected in each of the first three quarters in FY86 were made using the appropriate forecasting models. Of the twenty-one predictions made, thirteen compared favorably with the actual numbers of NUPOCS attained in the first three quarters of FY86, in the sense that the actual numbers lie within the 95% prediction interval. Forecast percentage errors ranged from 0 to 240 percent. At one extreme, the percentage error difference between actual and predicted contracts using the forecasting model for NRA 7 was less than 4% in each of the first three quarters of fiscal year 1986. At the other extreme, forecasting results using the model for NRA 1 failed to predict contracts within a 95 percent confidence region in all three quarters for FY86, with percentage errors ranging from 52 percent to 240 percent. The model underestimates the actual total NUPOCS recruited by NRA 1 by approximately 21 contracts for FY86 to date. It was also noted through the examination of the total contracts signed as of July 1986 that the Navy Recruiting Command met its FY86 NUPOC goals with two months of recruiting remaining in the fiscal year.

Possibilities for the poor performance in several of the forecasting models could be attributed to numerous factors, which include, but were not limited to the following: (1) The values of the forecasted explanatory variables used may themselves be inaccurate estimates of the actual values. (2) The parameter coefficient estimates ($\beta^*$), developed by the multiple regression analysis, may be poor due to various errors in the historical data. (3) The coefficient estimates were valid for the sample time period, but changes in the background conditions cause the estimates not to be useful in predicting. This can be attributed to abnormal or possibly altered conditions during the forecasting period. (4) The improper identification of the supply function.

It must be emphasized that the explanatory variables, included in the various forecasting models used in predicting NUPOCS, should not be interpreted as variables to control the number of contracts signed in a quarter. Just because a majority of the equations exclude recruiter strength, pay, and advertising costs, it does not mean that these variables were not important in the quarterly signing of contracts. All supply factors, which were included as possible explanatory variables in the forecasting models, were strongly believed to influence the recruiting effort. However, only those variables retained in the forecasting models were required for prediction purposes.

# APPENDIX A
## DATA

For an overview of the data, Table 6 through Table 11 in this appendix are complete representations of the raw quarterly historical data from fiscal years 1981 through 1985 for each of the six recruiting areas. They include the Nuclear Power Officer program contracts signed for the fiscal year and quarter with the corresponding numbers of recruiters, annual NUPOC goals, military to civilian pay ratio, unemployment rate, market share, and advertising costs. Table 12 contains the forecasted data for the explanatory variables for fiscal year 1986. Included in the data is the actual number of Navy Nuclear Propulsion Contracts signed by the recruiting areas as of July 1986. The above data are used to forecast contracts and make the appropriate comparisons. Table 13 illustrates the means, standard deviations and other statistics for the data contained in the first six tables.

## TABLE 6

## NUCLEAR POWER OFFICER CONTRACTS AND SUPPLY FACTORS NAVY RECRUITING AREA ONE

| YR | QTR | NUPOC | RECTR | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|---|---|
| 81 | 1 | 13 | 13.3 | 0.7796 | 0.0662 | 62 | 0.2497 | 28938 |
| 81 | 2 | 9 | 14.0 | 0.7570 | 0.0775 | 62 | 0.2497 | 22673 |
| 81 | 3 | 25 | 15.0 | 0.7357 | 0.0705 | 62 | 0.2497 | 14382 |
| 81 | 4 | 15 | 14.0 | 0.7111 | 0.0701 | 62 | 0.2497 | 18603 |
| 82 | 1 | 7 | 16.3 | 0.7073 | 0.0716 | 63 | 0.2265 | 30051 |
| 82 | 2 | 23 | 16.0 | 0.6831 | 0.0908 | 63 | 0.2265 | 32074 |
| 82 | 3 | 28 | 16.0 | 0.6824 | 0.0840 | 63 | 0.2265 | 18073 |
| 82 | 4 | 28 | 16.0 | 0.6871 | 0.0832 | 63 | 0.2265 | 42407 |
| 83 | 1 | 20 | 16.3 | 0.6904 | 0.0884 | 86 | 0.2661 | 18115 |
| 83 | 2 | 29 | 17.3 | 0.6877 | 0.0963 | 86 | 0.2661 | 28201 |
| 83 | 3 | 48 | 18.3 | 0.6838 | 0.0875 | 86 | 0.2661 | 15185 |
| 83 | 4 | 35 | 18.0 | 0.6821 | 0.0758 | 86 | 0.2661 | 18338 |
| 84 | 1 | 13 | 18.3 | 0.7063 | 0.0683 | 100 | 0.2392 | 27308 |
| 84 | 2 | 23 | 18.7 | 0.6985 | 0.0756 | 100 | 0.2392 | 22614 |
| 84 | 3 | 38 | 18.0 | 0.6909 | 0.0602 | 100 | 0.2392 | 15507 |
| 84 | 4 | 18 | 18.0 | 0.6841 | 0.0656 | 100 | 0.2392 | 20442 |
| 85 | 1 | 7 | 18.3 | 0.6997 | 0.0572 | 77 | 0.2558 | 28718 |
| 85 | 2 | 13 | 18.7 | 0.6943 | 0.0664 | 77 | 0.2558 | 23112 |
| 85 | 3 | 22 | 18.0 | 0.6891 | 0.0587 | 77 | 0.2558 | 15043 |
| 85 | 4 | 19 | 18.0 | 0.6839 | 0.0534 | 77 | 0.2558 | 21799 |

TABLE 7

NUCLEAR POWER OFFICER CONTRACTS AND SUPPLY FACTORS
NAVY RECRUITING AREA THREE

| YR | QTR | NUPOC | RECTR | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|---|---|
| 81 | 1 | 8 | 9.7 | 0.7796 | 0.0683 | 35 | 0.1320 | 11672 |
| 81 | 2 | 19 | 9.7 | 0.7570 | 0.0800 | 35 | 0.1320 | 13372 |
| 81 | 3 | 13 | 9.3 | 0.7357 | 0.0734 | 35 | 0.1320 | 9850 |
| 81 | 4 | 17 | 8.7 | 0.7111 | 0.0731 | 35 | 0.1320 | 9864 |
| 82 | 1 | 6 | 8.7 | 0.7073 | 0.0805 | 41 | 0.1448 | 10993 |
| 82 | 2 | 25 | 8.7 | 0.6831 | 0.0930 | 41 | 0.1448 | 15645 |
| 82 | 3 | 28 | 11.3 | 0.6824 | 0.0927 | 41 | 0.1448 | 12652 |
| 82 | 4 | 14 | 11.0 | 0.6871 | 0.0971 | 41 | 0.1448 | 16210 |
| 83 | 1 | 4 | 10.0 | 0.6904 | 0.1065 | 47 | 0.1372 | 16436 |
| 83 | 2 | 19 | 10.0 | 0.6877 | 0.1177 | 47 | 0.1372 | 10993 |
| 83 | 3 | 24 | 10.0 | 0.6838 | 0.1000 | 47 | 0.1372 | 8490 |
| 83 | 4 | 16 | 8.7 | 0.6821 | 0.0851 | 47 | 0.1372 | 9880 |
| 84 | 1 | 2 | 8.0 | 0.7063 | 0.0834 | 57 | 0.1353 | 10650 |
| 84 | 2 | 19 | 9.3 | 0.6985 | 0.0799 | 57 | 0.1353 | 16526 |
| 84 | 3 | 34 | 10.0 | 0.6909 | 0.0722 | 57 | 0.1353 | 6338 |
| 84 | 4 | 7 | 9.3 | 0.6841 | 0.0725 | 57 | 0.1353 | 6739 |
| 85 | 1 | 4 | 8.0 | 0.6997 | 0.0721 | 36 | 0.1205 | 9877 |
| 85 | 2 | 13 | 9.3 | 0.6944 | 0.0759 | 36 | 0.1205 | 17124 |
| 85 | 3 | 15 | 10.0 | 0.6891 | 0.0635 | 36 | 0.1205 | 6013 |
| 85 | 4 | 8 | 9.3 | 0.6840 | 0.0699 | 36 | 0.1205 | 8362 |

TABLE 8

NUCLEAR POWER OFFICER CONTRACTS AND SUPPLY FACTORS
NAVY RECRUITING AREA FOUR

| YR | QTR | NUPOC | RECTR | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|---|---|
| 81 | 1 | 8 | 11.3 | 0.7797 | 0.0872 | 50 | 0.1825 | 12047 |
| 81 | 2 | 11 | 11.0 | 0.7571 | 0.1028 | 50 | 0.1825 | 16583 |
| 81 | 3 | 20 | 11.3 | 0.7357 | 0.0867 | 50 | 0.1825 | 7330 |
| 81 | 4 | 15 | 11.7 | 0.7111 | 0.0867 | 50 | 0.1825 | 14949 |
| 82 | 1 | 6 | 11.7 | 0.7073 | 0.0973 | 54 | 0.1918 | 26948 |
| 82 | 2 | 16 | 11.3 | 0.6831 | 0.1211 | 54 | 0.1918 | 27016 |
| 82 | 3 | 14 | 10.6 | 0.6825 | 0.1083 | 54 | 0.1918 | 21843 |
| 82 | 4 | 24 | 10.0 | 0.6871 | 0.1150 | 54 | 0.1918 | 9870 |
| 83 | 1 | 10 | 10.0 | 0.6904 | 0.1272 | 65 | 0.2007 | 16969 |
| 83 | 2 | 14 | 11.0 | 0.6877 | 0.1393 | 65 | 0.2007 | 23654 |
| 83 | 3 | 24 | 12.7 | 0.6838 | 0.1179 | 65 | 0.2007 | 18799 |
| 83 | 4 | 25 | 15.3 | 0.6822 | 0.0982 | 65 | 0.2007 | 10693 |
| 84 | 1 | 10 | 15.3 | 0.7064 | 0.0969 | 81 | 0.1934 | 21765 |
| 84 | 2 | 13 | 15.7 | 0.6985 | 0.1010 | 81 | 0.1934 | 23589 |
| 84 | 3 | 25 | 15.0 | 0.6909 | 0.0888 | 81 | 0.1934 | 17779 |
| 84 | 4 | 15 | 15.0 | 0.6841 | 0.0842 | 81 | 0.1934 | 16738 |
| 85 | 1 | 2 | 15.3 | 0.6997 | 0.0845 | 57 | 0.1901 | 11128 |
| 85 | 2 | 7 | 15.7 | 0.6944 | 0.0916 | 57 | 0.1901 | 16148 |
| 85 | 3 | 15 | 15.0 | 0.6891 | 0.0761 | 57 | 0.1901 | 13330 |
| 85 | 4 | 10 | 15.0 | 0.6840 | 0.0786 | 57 | 0.1901 | 7194 |

TABLE 9

NUCLEAR POWER OFFICER CONTRACTS AND SUPPLY FACTORS
NAVY RECRUITING AREA FIVE

| YR | QTR | NUPOC | RECTR | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|---|---|
| 81 | 1 | 1 | 8.0 | 0.7797 | 0.0680 | 42 | 0.1558 | 4029 |
| 81 | 2 | 9 | 8.0 | 0.7571 | 0.0811 | 42 | 0.1558 | 7219 |
| 81 | 3 | 20 | 8.3 | 0.7357 | 0.0676 | 42 | 0.1558 | 2988 |
| 81 | 4 | 12 | 7.0 | 0.7111 | 0.0666 | 42 | 0.1558 | 8757 |
| 82 | 1 | 3 | 8.0 | 0.7073 | 0.0721 | 41 | 0.1464 | 19033 |
| 82 | 2 | 17 | 8.0 | 0.6831 | 0.0927 | 41 | 0.1464 | 19831 |
| 82 | 3 | 12 | 7.3 | 0.6825 | 0.0891 | 41 | 0.1464 | 14143 |
| 82 | 4 | 8 | 7.7 | 0.6871 | 0.0943 | 41 | 0.1464 | 13306 |
| 83 | 1 | 14 | 7.7 | 0.6904 | 0.1028 | 45 | 0.1345 | 8298 |
| 83 | 2 | 13 | 6.3 | 0.6877 | 0.1220 | 45 | 0.1345 | 9854 |
| 83 | 3 | 20 | 6.0 | 0.6838 | 0.0984 | 45 | 0.1345 | 8644 |
| 83 | 4 | 24 | 6.7 | 0.6822 | 0.0774 | 45 | 0.1345 | 8838 |
| 84 | 1 | 3 | 9.0 | 0.7064 | 0.0779 | 70 | 0.1668 | 14150 |
| 84 | 2 | 25 | 10.0 | 0.6985 | 0.0875 | 70 | 0.1668 | 14781 |
| 84 | 3 | 18 | 10.0 | 0.6909 | 0.0710 | 70 | 0.1668 | 16007 |
| 84 | 4 | 8 | 10.0 | 0.6841 | 0.0675 | 70 | 0.1668 | 11168 |
| 85 | 1 | 5 | 9.0 | 0.6997 | 0.0685 | 50 | 0.1641 | 15634 |
| 85 | 2 | 11 | 10.0 | 0.6944 | 0.0838 | 50 | 0.1641 | 15285 |
| 85 | 3 | 20 | 10.0 | 0.6891 | 0.0708 | 50 | 0.1641 | 12007 |
| 85 | 4 | 8 | 10.0 | 0.6840 | 0.0685 | 50 | 0.1641 | 7678 |

TABLE 10

NUCLEAR POWER OFFICER CONTRACTS AND SUPPLY FACTORS
NAVY RECRUITING AREA SEVEN

| YR | QTR | NUPOC | RECTR | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|---|---|
| 81 | 1 | 8 | 10.0 | 0.7797 | 0.0598 | 33 | 0.1218 | 7023 |
| 81 | 2 | 6 | 9.3 | 0.7571 | 0.0576 | 33 | 0.1218 | 10987 |
| 81 | 3 | 7 | 9.0 | 0.7357 | 0.0572 | 33 | 0.1218 | 6316 |
| 81 | 4 | 8 | 9.3 | 0.7111 | 0.0585 | 33 | 0.1218 | 6388 |
| 82 | 1 | 5 | 9.7 | 0.7073 | 0.0599 | 37 | 0.1325 | 9788 |
| 82 | 2 | 4 | 8.7 | 0.6831 | 0.0660 | 37 | 0.1325 | 21102 |
| 82 | 3 | 23 | 7.0 | 0.6825 | 0.0693 | 37 | 0.1325 | 7461 |
| 82 | 4 | 22 | 8.0 | 0.6871 | 0.0773 | 37 | 0.1325 | 9244 |
| 83 | 1 | 5 | 8.3 | 0.6904 | 0.0848 | 40 | 0.1121 | 7855 |
| 83 | 2 | 20 | 8.7 | 0.6877 | 0.0977 | 40 | 0.1121 | 9060 |
| 83 | 3 | 20 | 8.3 | 0.6838 | 0.0914 | 40 | 0.1121 | 5246 |
| 83 | 4 | 14 | 7.7 | 0.6822 | 0.0847 | 40 | 0.1121 | 8179 |
| 84 | 1 | 4 | 8.0 | 0.7064 | 0.0743 | 52 | 0.1241 | 6822 |
| 84 | 2 | 17 | 8.0 | 0.6985 | 0.0717 | 52 | 0.1241 | 8180 |
| 84 | 3 | 11 | 7.3 | 0.6909 | 0.0657 | 52 | 0.1241 | 6502 |
| 84 | 4 | 15 | 6.0 | 0.6841 | 0.0641 | 52 | 0.1241 | 6995 |
| 85 | 1 | 5 | 8.0 | 0.6997 | 0.0635 | 35 | 0.1143 | 3070 |
| 85 | 2 | 12 | 8.0 | 0.6944 | 0.0800 | 35 | 0.1143 | 6736 |
| 85 | 3 | 12 | 7.7 | 0.6891 | 0.0717 | 35 | 0.1143 | 5905 |
| 85 | 4 | 4 | 6.0 | 0.6840 | 0.0744 | 35 | 0.1143 | 3369 |

TABLE 11

NUCLEAR POWER OFFICER CONTRACTS AND SUPPLY FACTORS
NAVY RECRUITING AREA EIGHT

| YR | QTR | NUPOC | RECTR | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|---|---|
| 81 | 1 | 3 | 10.3 | 0.7797 | 0.0713 | 41 | 0.1582 | 9631 |
| 81 | 2 | 15 | 11.0 | 0.7571 | 0.0817 | 41 | 0.1582 | 15677 |
| 81 | 3 | 26 | 10.7 | 0.7357 | 0.0662 | 41 | 0.1582 | 11380 |
| 81 | 4 | 21 | 11.0 | 0.7111 | 0.0712 | 41 | 0.1582 | 15598 |
| 82 | 1 | 5 | 11.0 | 0.7073 | 0.0805 | 44 | 0.1573 | 20861 |
| 82 | 2 | 17 | 11.0 | 0.6831 | 0.0994 | 44 | 0.1573 | 22009 |
| 82 | 3 | 21 | 11.0 | 0.6825 | 0.0937 | 44 | 0.1573 | 21503 |
| 82 | 4 | 32 | 12.0 | 0.6871 | 0.1018 | 44 | 0.1573 | 22012 |
| 83 | 1 | 5 | 12.0 | 0.6904 | 0.1092 | 54 | 0.1594 | 21561 |
| 83 | 2 | 22 | 13.0 | 0.6877 | 0.1198 | 54 | 0.1594 | 11377 |
| 83 | 3 | 21 | 13.7 | 0.6838 | 0.0993 | 54 | 0.1594 | 12442 |
| 83 | 4 | 23 | 10.0 | 0.6821 | 0.0824 | 54 | 0.1594 | 5948 |
| 84 | 1 | 9 | 13.0 | 0.7063 | 0.0831 | 59 | 0.1412 | 10765 |
| 84 | 2 | 14 | 14.7 | 0.6985 | 0.0880 | 59 | 0.1412 | 23787 |
| 84 | 3 | 24 | 14.3 | 0.6909 | 0.0731 | 59 | 0.1412 | 27144 |
| 84 | 4 | 15 | 12.3 | 0.6841 | 0.0736 | 59 | 0.1412 | 31456 |
| 85 | 1 | 2 | 13.0 | 0.6997 | 0.0718 | 47 | 0.1552 | 17217 |
| 85 | 2 | 10 | 14.7 | 0.6943 | 0.0795 | 47 | 0.1552 | 13725 |
| 85 | 3 | 17 | 14.3 | 0.6891 | 0.0694 | 47 | 0.1552 | 10016 |
| 85 | 4 | 19 | 12.3 | 0.6839 | 0.0713 | 47 | 0.1552 | 9844 |

TABLE 12

FORECASTS OF SUPPLY FACTORS AND NUPOCS ATTAINED FOR FY 86 (ALL NRA'S & NRC)

| NRA | YR | QTR | RECTRS | RATIO | UNEMP | MKTSHR | GOALS | ADVER | NUPOCS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 86 | 1 | 18 | .6990 | .0575 | .2406 | 69 | 28718 | 8 |
| 1 | 86 | 2 | 18 | .6937 | .0573 | .2406 | 69 | 23112 | 4 |
| 1 | 86 | 3 | 18 | .6885 | .0580 | .2406 | 69 | 15043 | 42 |
| 1 | 86 | 4 | 18 | .6834 | .0568 | .2406 | 69 | 21799 | 7 |
| 3 | 86 | 1 | 9 | .6990 | .0696 | .1240 | 35 | 9877 | 2 |
| 3 | 86 | 2 | 9 | .6937 | .0689 | .1240 | 35 | 17124 | 14 |
| 3 | 86 | 3 | 9 | .6885 | .0689 | .1240 | 35 | 6013 | 13 |
| 3 | 86 | 4 | 9 | .6834 | .0683 | .1240 | 35 | 8362 | 7 |
| 4 | 86 | 1 | 15 | .6990 | .0842 | .1938 | 55 | 11128 | 6 |
| 4 | 86 | 2 | 15 | .6937 | .0815 | .1938 | 55 | 16148 | 20 |
| 4 | 86 | 3 | 15 | .6885 | .0779 | .1938 | 55 | 13330 | 24 |
| 4 | 86 | 4 | 15 | .6834 | .0764 | .1938 | 55 | 7194 | 10 |
| 5 | 86 | 1 | 10 | .6990 | .0763 | .1687 | 48 | 15634 | 6 |
| 5 | 86 | 2 | 10 | .6937 | .0742 | .1687 | 48 | 15285 | 12 |
| 5 | 86 | 3 | 10 | .6885 | .0715 | .1687 | 48 | 12007 | 30 |
| 5 | 86 | 4 | 10 | .6834 | .0716 | .1687 | 48 | 7678 | 5 |
| 7 | 86 | 1 | 6 | .6990 | .0779 | .1164 | 33 | 3070 | 3 |
| 7 | 86 | 2 | 6 | .6937 | .0795 | .1164 | 33 | 6736 | 11 |
| 7 | 86 | 3 | 6 | .6885 | .0792 | .1164 | 33 | 5905 | 14 |
| 7 | 86 | 4 | 6 | .6834 | .0806 | .1164 | 33 | 3369 | 4 |
| 8 | 86 | 1 | 12 | .6990 | .0738 | .1565 | 45 | 17217 | 6 |
| 8 | 86 | 2 | 12 | .6937 | .0730 | .1565 | 45 | 13725 | 10 |
| 8 | 86 | 3 | 12 | .6885 | .0697 | .1565 | 45 | 10016 | 22 |
| 8 | 86 | 4 | 12 | .6834 | .0693 | .1565 | 45 | 9844 | 10 |
| 0 | 86 | 1 | 70 | .6990 | .0727 | 1 | 285 | 85644 | 31 |
| 0 | 86 | 2 | 70 | .6937 | .0718 | 1 | 285 | 92130 | 70 |
| 0 | 86 | 3 | 70 | .6885 | .0702 | 1 | 285 | 62314 | 145 |
| 0 | 86 | 4 | 70 | .6834 | .0697 | 1 | 285 | 58246 | 43 |

TABLE 13

DESCRIPTIVE STATISTICS OF QUARTERLY DATA

| Variables | N | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|
| NUPOCS | 120 | 15.050 | 14.000 | 14.602 | 8.611 | 0.786 |
| RECTRS | 120 | 11.339 | 10.000 | 11.226 | 3.412 | 0.312 |
| RATIO | 120 | 0.70174 | 0.69066 | 0.69850 | 0.02595 | 0.00237 |
| UNEMP | 120 | 0.08214 | 0.07970 | 0.08118 | 0.01670 | 0.00152 |
| GOALS | 120 | 53.37 | 50.00 | 52.13 | 16.28 | 1.49 |
| MKTSHR | 120 | 0.16698 | 0.15655 | 0.16467 | 0.04331 | 0.00395 |
| ADVER | 120 | 14546 | 13351 | 14141 | 7313 | 668 |

| Variables | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| NUPOCS | 1.000 | 48.000 | 8.000 | 20.750 |
| RECTRS | 6.000 | 18.700 | 8.700 | 14.225 |
| RATIO | 0.68216 | 0.77968 | 0.68400 | 0.70708 |
| UNEMP | 0.05340 | 0.13930 | 0.07020 | 0.09242 |
| GOALS | 33.00 | 100.00 | 41.00 | 62.00 |
| MKTSHR | 0.11210 | 0.26610 | 0.13450 | 0.19180 |
| ADVER | 2988 | 42407 | 8777 | 18750 |

# APPENDIX B
# MULTICOLLINEARITY

Table 14 through Table 19 present the correlations between the independent variables for the quarterly data by the entire Navy Recruiting Command (NRC) and Navy Recruiting Areas (NRA). Starred values (*) are correlation coefficients that exceed 0.70.

TABLE 14
NRC CORRELATION OF INDEPENDENT VARIABLES

| VARS | RECTRS | RATIO | UNEMP | GOALS | ADVER |
|---|---|---|---|---|---|
| RECTRS | 1.00000 | | | | |
| RATIO | -0.37490 | 1.00000 | | | |
| UNEMP | -0.28990 | -0.34332 | 1.00000 | | |
| GOALS | 0.64925 | -0.39275 | 0.05053 | 1.00000 | |
| ADVER | -0.05384 | -0.22141 | 0.39947 | 0.11670 | 1.00000 |

TABLE 15

NRA 1 CORRELATION OF INDEPENDENT VARIABLES

| VARS | RECTRS | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|
| RECTRS | 1.00000 | | | | | |
| RATIO | *-0.71667 | 1.00000 | | | | |
| UNEMP | -0.20848 | -0.17519 | 1.00000 | | | |
| GOALS | *0.75973 | -0.42870 | -0.12607 | 1.00000 | | |
| MKTSHR | 0.19274 | 0.01394 | -0.01465 | 0.24294 | 1.00000 | |
| ADVER | -0.15231 | 0.07276 | 0.21180 | -0.28398 | -0.45280 | 1.00000 |

TABLE 16

NRA 3 CORRELATION OF INDEPENDENT VARIABLES

| VARS | RECTRS | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|
| RECTRS | 1.00000 | | | | | |
| RATIO | -0.10681 | 1.00000 | | | | |
| UNEMP | 0.35427 | -0.35782 | 1.00000 | | | |
| GOALS | -0.03975 | -0.39849 | 0.25115 | 1.00000 | | |
| MKTSHR | 0.29221 | -0.13644 | 0.59790 | 0.37280 | 1.00000 | |
| ADVER | 0.13920 | 0.06654 | 0.42523 | -0.10332 | 0.29257 | 1.00000 |

TABLE 17
NRA 4 CORRELATION OF INDEPENDENT VARIABLES

| VARS | RECTRS | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|
| RECTRS | 1.00000 | | | | | |
| RATIO | -0.28785 | 1.00000 | | | | |
| UNEMP | -0.58814 | -0.25381 | 1.00000 | | | |
| GOALS | 0.56753 | -0.39640 | 0.03819 | 1.00000 | | |
| MKTSHR | 0.13954 | *-0.72018 | 0.58515 | 0.55156 | 1.00000 | |
| ADVER | -0.13224 | -0.21110 | 0.51768 | 0.30451 | 0.33467 | 1.00000 |

TABLE 18
NRA 5 CORRELATION OF INDEPENDENT VARIABLES

| VARS | RECTRS | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|
| RECTRS | 1.00000 | | | | | |
| RATIO | -0.04290 | 1.00000 | | | | |
| UNEMP | -0.52141 | -0.34718 | 1.00000 | | | |
| GOALS | 0.66204 | -0.22052 | -0.21693 | 1.00000 | | |
| MKTSHR | *0.88362 | 0.18783 | -0.67371 | 0.64133 | 1.00000 | |
| ADVER | 0.28053 | -0.50731 | 0.09340 | 0.26707 | 0.17152 | 1.00000 |

TABLE 19

NRA 7 CORRELATION OF INDEPENDENT VARIABLES

| VARS | RECTRS | RATIO | UNEMP | GOALS | MKTSHR | ADVER |
|---|---|---|---|---|---|---|
| RECTRS | 1.00000 | | | | | |
| RATIO | 0.66758 | 1.00000 | | | | |
| UNEMP | -0.23959 | -0.56571 | 1.00000 | | | |
| GOALS | -0.44755 | -0.35189 | 0.17716 | 1.00000 | | |
| MKTSHR | 0.12399 | 0.09115 | -0.54213 | 0.12440 | 1.00000 | |
| ADVER | 0.32521 | -0.01969 | -0.08408 | -0.03632 | 0.51370 | 1.00000 |

## APPENDIX C
## AUTOCORRELATION

The following APL computer program (Table 20) calculates the estimate of the correlation coefficient ($\rho$) from the Durbin-Watson statistic, and transforms the values of the observations to be used in the generalized least squares regression.

TABLE 20

TRANSFORMATION OF AUTOCORRELATED OBSERVATIONS

```
    ∇ P
⍝THE PURPOSE OF THIS PROGRAM IS TO TRANSFORM DATA
⍝CORRESPONDING TO VALUES DISPLAYING AUTOCORRELATION
⍝USING THE DURBIN-WATSON STATISTIC TO COMPUTE
⍝THE ESTIMATER FOR RHO. INPUTS REQUIRED ARE THE
⍝DURBIN-WATSON STATISTIC AND THE DATA FILE INCLUDING
⍝THE NUMBERS OF ROWS AND COLUMNS.
 'INPUT DURBIN WATSON STATISTIC'
DW←⎕
RHO←1-(DW 2)
⍝ENTER THE DATA USED IN THE OLS REGRESSION
 'INPUT DATA FILE'
DATA←⎕
 'INPUT NUMBER OF ROWS'
N←⎕
 'INPUT NUMBER OF COLUMNS'
CC←⎕
⍝COMPUTE TRANSFORMATION MATRIX (PSTAR),
⍝AND THE TRANSFORMED DATA MATRICES
⍝XSTAR (INDEPENDENT VARIABLES) AND
⍝YSTAR (DEPENDENT VARIABLE)
PSTAR←(N,N)ρ0
PSTAR[1;1]←((1-(RHO*2))*0.5)
I←0
DD←CC-1
LOOPI:((N-1)<I←I+1)/OVER
→(I=N)/OVER
PSTAR[I+1;I]←-RHO
PSTAR[I+1;I+1]←1
→LOOPI
OVER:
 'THE ESTIMATE FOR RHO IS'
RHO
 'PSTAR IS'
PSTAR
Y←(N,1)ρDATA[;1]
X←(N,-DD)↑DATA
X←((N,1)ρ1),X
YSTAR←PSTAR+.×Y
 'YSTAR IS'
YSTAR
XSTAR←PSTAR+.×X
 'XSTAR IS'
XSTAR
 'THE NEW DATA FILE (DATA1) TO USE FOR OLS REGRESSION'
DATA1←YSTAR,XSTAR
DATA1
⍝USE THE CMSWRITE FUNCTION TO CREATE A DATA
⍝FILE WITH THE NEW TRANSFORMED VALUES. RUN
⍝OLS REGRESSION ON THE NEW VALUES TO OBTAIN
⍝THE ESTIMATED GENERALIZED OLS ESTIMATER.
```

## APPENDIX D

## NRA FORECASTING MODEL REGRESSION RESULTS

The following tables present the analysis of variance and parameter estimates for the least squares multiple regression runs on the quarterly historical data by Navy Recruiting Area (NRA). Significant variables were chosen by regression procedure STEPWISE.

TABLE 21

REGRESSION NRA 1 - ANOVA AND PARAMETER ESTIMATES

| VARIABLE | β * | STD ERROR | T-Statistic |
|---|---|---|---|
| INTERCEP | -62.21 | 11.07 | -5.618 |
| RECTRS1 | 2.15 | 0.49 | 4.362 |
| UNEMP1 | 663.28 | 80.17 | 8.274 |
| QTR1 | -10.54 | 2.58 | -4.082 |
| QTR3 | 3.98 | 2.56 | 1.556 |

| SOURCE | DF | SS | MS | F VALUE |
|---|---|---|---|---|
| MODEL | 5 | 14383.0 | 2876.60 | 184.90 |
| ERROR | 14 | 217.8 | 15.56 | |
| C TOTAL | 19 | 14601.0 | | |

| | | |
|---|---|---|
| R-SQUARE | 0.99 | STD ERROR = 3.94 |
| ADJ R-SQ | 0.98 | |
| DURBIN-WATSON | 2.31 | |

TABLE 22

REGRESSION NRA 3 - ANOVA AND PARAMETER ESTIMATES

| VARIABLE | β * | STD ERROR | T-Statistic |
|---|---|---|---|
| INTERCEP | -40.04 | 11.74 | -3.411 |
| MKTSHR | 388.72 | 86.08 | 4.516 |
| QTR1 | -7.31 | 3.59 | -2.035 |
| QTR2 | 6.94 | 2.42 | 2.874 |
| QTR3 | 10.92 | 3.68 | 2.967 |

| SOURCE | DF | SS | MS | F VALUE |
|---|---|---|---|---|
| MODEL | 5 | 10520.00 | 2103.90 | 122.47 |
| ERROR | 15 | 257.68 | 17.18 | |
| C TOTAL | 20 | 10777.00 | | |

| | | |
|---|---|---|
| R-SQUARE | 0.98 | STD ERROR = 4.14 |
| ADJ R-SQ | 0.97 | |
| DURBIN-WATSON | 2.90 | |

TABLE 23

REGRESSION NRA 4 - ANOVA AND PARAMETER ESTIMATES

| VARIABLE | β * | STD ERROR | T-Statistic |
|---|---|---|---|
| UNEMP1 | 179.62 | 49.48 | 3.630 |
| QTR1 | -10.23 | 2.27 | -4.511 |
| QTR2 | -5.72 | 2.09 | -2.738 |

| SOURCE | DF | SS | MS | F VALUE |
|---|---|---|---|---|
| MODEL | 4 | 5498.50 | 1374.6 | 98.15 |
| ERROR | 15 | 210.07 | 14.0 | |
| C TOTAL | 19 | 5708.60 | | |

| | | |
|---|---|---|
| R-SQUARE | 0.96 | STD ERROR = 3.74 |
| ADJ R-SQ | 0.95 | |
| DURBIN-WATSON | 2.22 | |

TABLE 24

REGRESSION NRA 5 - ANOVA AND PARAMETER ESTIMATES

| VARIABLE | β * | STD ERROR | T-Statistic |
|---|---|---|---|
| UNEMP1 | 151.08 | 65.84 | 2.295 |
| QTR1 | -7.82 | 2.98 | -2.622 |

| SOURCE | DF | SS | MS | F VALUE |
|---|---|---|---|---|
| MODEL | 3 | 6069.50 | 2023.20 | 82.56 |
| ERROR | 16 | 392.08 | 24.51 | |
| C TOTAL | 19 | 6461.60 | | |

| | | |
|---|---|---|
| R-SQUARE | 0.94 | STD ERROR = 4.95 |
| ADJ R-SQ | 0.93 | |
| DURBIN-WATSON | 2.64 | |

TABLE 25

REGRESSION NRA 7 - ANOVA AND PARAMETER ESTIMATES

| VARIABLE | β * | STD ERROR | T-Statistic |
|---|---|---|---|
| INTERCEP | -8.06 | 7.77 | -1.037 |
| UNEMP1 | 226.08 | 97.76 | 2.313 |
| ADVER1 | 6.04E-4 | 3.28E-4 | 1.840 |
| QTR1 | -7.85 | 2.85 | -2.754 |

| SOURCE | DF | SS | MS | F VALUE |
|---|---|---|---|---|
| MODEL | 4 | 2927.00 | 731.98 | 28.98 |
| ERROR | 15 | 378.71 | 25.25 | |
| C TOTAL | 19 | 3305.70 | | |

| | | |
|---|---|---|
| R-SQUARE | 0.89 | STD ERROR = 5.02 |
| ADJ R-SQ | 0.85 | |
| DURBIN-WATSON | 2.04 | |

TABLE 26

REGRESSION NRC - ANOVA AND PARAMETER ESTIMATES

| VARIABLE | $\beta$ * | STD ERROR | T-Statistic |
|---|---|---|---|
| UNEMP | 1015.10 | 232.67 | 5.111 |
| GOALS | 1.19E-1 | 5.18E-2 | 2.311 |
| QTR1 | -64.08 | 10.08 | -6.360 |
| QTR1 | -23.49 | 9.57 | -2.454 |
| QTR3 | 27.83 | 10.22 | 2.722 |

| SOURCE | DF | SS | MS | F VALUE |
|---|---|---|---|---|
| MODEL | 6 | 2.60E5 | 43277.00 | 202.43 |
| ERROR | 14 | 2.99E3 | 213.79 | |
| C TOTAL | 20 | 2.62E5 | | |

| | | |
|---|---|---|
| R-SQUARE | 0.99 | STD ERROR = 14.62 |
| ADJ R-SQ | 0.98 | |
| DURBIN-WATSON | 2.36 | |

## APPENDIX E
## PREDICTION INTERVALS

The APL program in this appendix computes the 95% confidence interval using the procedure discussed in Chapter 5.B. The inputs required include the matrix of the explanatory variables, the t-statistic at (n-p-1) degrees of freedom and $\alpha = 0.025$, the forecasted explanatory variables, estimated standard error of the regression model and the forecasted value of NUPOCS.

TABLE 27

NINETY-FIVE PERCENT CONFIDENCE INTERVAL CALCULATION OF NUPOCS

```
    ∇CI
[1]  'INPUT THE EXPLANATORY VARIABLE DATA FILE'
[2]  AA←⎕
[3]  'THE SHAPE OF THE EXPLANATORY VARIABLE DATA FILE IS'
[4]  ⍴AA
[5]  'INPUT THE NUMBER OF ROWS IN THE DATA FILE'
[6]  R←⎕
[7]  'INPUT T(N-P-1,0.975)'
[8]  TTT←⎕
[9]  AA←((R,1)⍴1),AA
[10] AAT←⍉AA
[11] AAA←AAT+.×AA
[12] AAI←⌹AAA
[13] 'INPUT THE X VECTOR FOR THE 1ST QTR'
[14] X0←⎕
[15] 'INPUT THE STD ERROR ESTIMATE'
[16] S←⎕
[17] 'INPUT YHAT FOR THE 1ST QTR'
[18] YHAT←⎕
[19] CIL←YHAT-TTT×S×(((⍉X0)+.×AAI+.×X0)*0.5)
[20] CIU←YHAT+TTT×S×(((⍉X0)+.×AAI+.×X0)*0.5)
[21] 'THE 95 PERCENT CONFIDENCE INTERVAL FOR 1ST QTR IS'
[22] CIL,CIU
[23] 'INPUT THE X VECTOR FOR THE 2ND QUARTER'
[24] X0←⎕
[25] 'INPUT YHAT FOR THE 2ND QTR'
[26] YHAT←⎕
[27] CIL←YHAT-TTT×S×(((⍉X0)+.×AAI+.×X0)*0.5)
[28] CIU←YHAT+TTT×S×(((⍉X0)+.×AAI+.×X0)*0.5)
[29] 'THE 95 PERCENT CI FOR 2ND QTR IS'
[30] CIL,CIU
[31] 'INPUT THE X VECTOR FOR 3RD QUARTER'
[32] X0←⎕
[33] 'INPUT THE ESTIMATE FOR 3RD QTR'
[34] YHAT←⎕
[35] CIL←YHAT-TTT×S×(((⍉X0)+.×AAI+.×X0)*0.5)
[36] CIU←YHAT+TTT×S×(((⍉X0)+.×AAI+.×X0)*0.5)
[37] 'THE 95 PERCENT CI FOR 3RD QUARTER IS'
[38] CIL,CIU
[39] 'INPUT THE X VECTOR FOR 4TH QUARTER'
[40] X0←⎕
[41] 'INPUT THE ESTIMATE FOR 4TH QUARTER FOR NUPOCS'
[42] YHAT←⎕
[43] CIL←YHAT-TTT×S×(((⍉X0)+.×AAI+.×X0)*0.5)
[44] CIU←YHAT+TTT×S×(((⍉X0)+.×AAI+.×X0)*0.5)
[45] 'THE 95 PERCENT CI FOR NUPOCS IN THE 4TH QUARTER'
[46] CIL,CIU
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## LIST OF REFERENCES


1. Rand Corporation Note N-1297-MRAL, *Forecasting Enlisted Supply: Projections for 1979-1990*, by R.L. Fernandez, September 1979.

2. Center of Naval Analyses Report CNS 1073, *Recruiters, Quotas and the Number of Enlistments*, by CDR W.F. Shughart, USN, December 1976.

3. Rand Corporation Report P-6967, *Active Enlisted Supply: Prospects and Policy Options*, by J.R. Hosek, R.L. Fernandez, and D.W. Grissmer, March 1984.

4. Center for Applied Business Research (Duke University) Report, *Budget Allocation and Enlistment Prediction*, by R.L. Morey, May 1979.

5. Carroll, V.P., and others, "The Navy Enlisted Marketing Experiment," *Marketing Science*, v. 4, pp. 352-374, Fall 1985.

6. Goldberg, L., "Recruiters, Advertising, and Navy Enlistments," *Naval Research Logistics Quarterly*, v. 29, June 1982.

7. Morey, R.L. and McCann, J.M., "Armed Services Recruiter Research: Issues, Findings, and Needs," *Naval Research Logistics Quarterly*, v. 30, pp. 697-719, 1983.

8. Draper, H.R. and Smith, H., *Applied Regression Analysis (2nd)*, John Wiley & Sons, Inc., 1981.

9. Koutsoyiannis, A., *Theory of Econometrics*, The MacMillian Press, LTD., 1977.

10. Center for Naval Analyses Report CNS 1168, *Enlisted Supply: Past, Present, and Future*, by L. Goldberg, September 1983.

11. Navy Recruiting Command Memorandum CNRC 312: Serial 5211 to Navy Recruiting Commands, Subject: *Assignment of Officer Recruiters to Nuclear Power Recruiting*, 3 September 1981.

12. Department of the Navy, (COMNAVCRUITCOM INSTRUCTION 1650.8F), *Navy Recruiting Command Competition System (NRCCS) Field Guide*, November 1986.

13. Epps, T.W., "An Econometric Analysis of the Effectiveness of the U.S. Army's 1971 Paid Advertising Campaign," *Applied Economics*, v. 5, pp. 261-269, 1973.

14. College Placement Council, *Salary Survey*, Bethlehem, Pennsylvania, January, March, and July 1980-1985.

15. Rand Corporation Report P-7022, *Enlistment Supply, Recruiter Objectives, and the All Volunteer Army*, by J.N. Dertouzos, September 1984.

16. Office of the Secretary of Defense (Manpower, Reserve Affairs and Logistics), *Profile of American Youth*, Washington, D.C., 1980.

17. Defense Manpower Data Center Report, *Youth Attitude Tracking Study*, by R. Bray, E. Cavanaugh, and K. Jordan, Fall 1984.

18. Wheelwright, S.C., & Makridakis, S., *Forecasting Methods for Management*, John Wiley & Sons, Inc., 1980.

19. Johnson, Malcom, *Draftsman Displays, A Graphical Technique for Exploratory Data Analysis*, MS Thesis, Naval Postgraduate School, Monterey, California, June 1984.

20. Tukey, P.A., and others, *Graphical Methods for Data Analysis*, Duxbury Press, 1983.

21. Judge, G.G., and others, *Introduction to the Theory and Practice of Econometrics*, John Wiley & Sons Inc., 1982.

22. Maurice, S.C. and Smithson, C.W., *Managerial Economics (2nd)*, Richard D. Irwin, Inc., 1985.

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